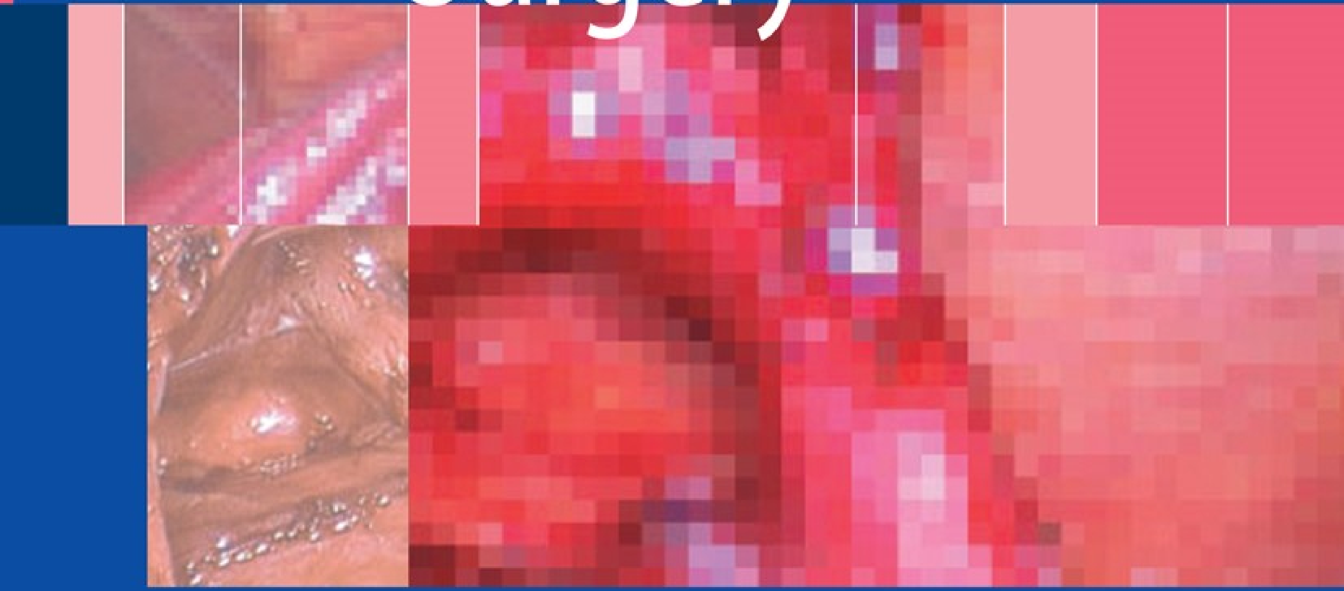
Vipul R. Patel
Editor

Robotic Urologic Surgery



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Robotic Urologic Surgery

Vipul R. Patel (Ed.)

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Springer

Vipul R. Patel, MD
Director, Center for Robotic and Computer-Assisted Surgery and for Robotic and Minimally Invasive Urologic Surgery
Associate Clinical Professor of Surgery and Associate Professor of Bioinformatics
The Ohio State University Medical Center
Columbus, OH, USA

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This book is dedicated to my wife Sejal
and my two children Ela and Evan

Foreword

Urologic surgery has always been associated with unusual diagnostic and therapeutic approaches to pathologic disorders. Endoscopy, contrast radiography, and extracorporeal shock wave lithotripsy are a few of the innovations promulgated by urologists to address physiological dysfunctions of the gastrointestinal urinary tract. Robotic-assisted laparoscopic surgery is a natural extension of the pioneering efforts of endourologists to perform closed, controlled manipulations of the urinary system. It is appealing technology that challenges surgical scientists to accurately define and extend the indications for robotics in the surgical patient. Dr. Vipul Patel and his contributors have elegantly provided for all of us the foundation to acquire and amplify the skills of robotic surgery and improve the precision of our operative endeavors.

Robert R. Bahnson, MD
E. Christopher Ellison, MD

Preface

Surgery has traditionally been a specialty within the medical profession that has revolved around invasive procedures to treat various maladies. Initially, trauma induced by a therapeutic procedure was necessary and reasonable to provide benefit to the patient. But now, the innovation of digital imaging technology, combined with optical engineering and improved video displays, allows surgeons to operate inside body cavities for therapeutic intervention without the larger incisions.

Minimally invasive surgery has changed the route of access and has significantly and irrevocably changed the surgical treatment of most disease processes. Patients still undergo interventions to treat disease, but minimally invasive surgery makes possible a reduction or complete elimination of the "collateral damage" required to gain access to the organ requiring surgery. While the benefits of this approach are numerous for the patient, early technology limited the application of minimally invasive surgery to only some procedures. Specifically, surgeons using standard minimally invasive techniques lost the value of natural three-dimensional image, depth perception, and articulated movements. Magnification of small structures was often difficult and instruments were rigid and without joints. Robotic surgery has provided the technology to address these limitations and allow the application of minimally invasive surgery to a broader spectrum of patients and their diseases.

The robotic revolution in surgery began at the dawn of the new millennium and has seen its most robust growth in the area of urologic surgery. Urologists and patients alike have embraced this technological leap to create a whole new era in urology. This book represents the first ever robotic surgery text dedicated solely to the field of urologic surgery and therefore a milestone all to itself. The work is a compilation of the knowledge and experience of the worlds foremost robotic urologic surgeons. The field of surgery has forever been changed for the betterment of surgical technique and patient care.

Vipul R. Patel

Contents

Contributors

Clement-Claude Abbou, MD
Urology Service
CHU Henri Mondor
Créteil-Cedex, France

Thomas E. Ahlering, MD
Department of Urology
University of California, Irvine Medical Centre
Orange, CA, USA

David M. Albala, MD
Department of Urology
Duke University Medical Center
Durham, NC, USA

Justin M. Albani, MD
Surgery, Division of Urology
Penn Presbyterian Medical Center
Philadelphia, PA, USA

Scott Van Appledorn, MD
Department of Urology
Gulf Stream Urology Associates
Fort Pierce, FL, USA

Fatih Atug, MD, FACS, MHA
Tulane University Health Sciences Center
Department of Urology
Center for Minimally Invasive Urologic Surgery
New Orleans, LA, USA

Robert R. Bahnson, MD, FACS
Division of Urology
The Ohio State University
Columbus, OH, USA

Garth H. Ballantyne, MD, FACS, FASCRS
Department of Surgery
Hackensack University Medical Centre
Hackensack, NJ, USA

Eric Barret, MD
Department of Urology
L'Institute Mutualiste Montsouris
Paris, France

Kristy M. Borawski, MD
Department of Surgery / Division of Urology
Duke University Medical Center
Durham, NC, USA

Geoffrey N. Box, MD
Department of Urology
The Ohio State University
Columbus, OH, USA

Robert I. Carey, MD, PhD
Department of Urology
University of Miami
Miami, FL, USA

Xavier Cathelineau, MD
Department of Urology
L'Institute Mutualiste Montsouris
Paris, France

George K. Chow, MD
Department of Urology
Mayo Clinic
Rochester, MN, USA

Anthony J. Costello, MD
The Epworth Centre
Richmond, Australia

Daniel S. Elliott, MD
Department of Urology
Mayo Clinic
Rochester, MN, USA

E. Christopher Ellison, MD
Department of Surgery
The Ohio State University
Columbus, OH, USA

Michael Esposito, MD
Department of Urology
Hackensack University Medical Center
Hackensack, NJ, USA

Inderbir S. Gill, MD
Section of Laparoscopic and Robotic Surgery
Glickman Urological Institute
Cleveland Clinic
Cleveland, OH, USA

Michael Gong, MD, PhD
Department of Urology
The Ohio State University
Columbus, OH, USA

Khurshid A. Guru, MD
Department of Urologic Oncology
Roswell Park Cancer Institute
Buffalo, NY, USA

Justin D. Harmon, DO
Department of Urology
Robert Wood Johnson Medical School
Cooper University Hospital
Camden, NJ, USA

Nicholas J. Hegarty, MD, PhD, FRCS(Urol)
Glickman Urological Institute
Cleveland Clinic
Cleveland, OH, USA

Ashok K. Hemal, MBBS, MS, Dip.NB, MCh, MAMS, FICS, FACS, FAMS
Department of Urology
All India Institute of Medical Sciences
New Delhi, India

András Hoznek, MD
Urology Service
CHU Henri Mondor
Créteil-Cedex, France

Hyung L. Kim, MD
Department of Urologic Oncology
Roswell Park Cancer Institute
Buffalo, NY, USA

Amy Krambeck, MD
Department of Urology
Mayo Clinic
Rochester, MN, USA

Ali Riza Kural, MD
Department of Urology
University of Istanbul, Cerrahpasa School of Medicine
Beslktas, Istanbul, Turkey

David I. Lee, MD
Division of Urology
Penn Presbyterian Medical Center
Philadelphia, PA, USA

James O. L'Esperance, MD
Department of Urology
Duke University Medical Center
Durham, NC, USA

Raymond J. Leveillee, MD
Department of Urology
University of Miami
Miami, FL, USA

Michael Louie, MD
Department of Urology
The Ohio State University Medical Center
Columbus, OH, USA

Garrett S. Matsunaga, MD
Department of Urology
University of California, Irvine Medical Centre
Orange, CA, USA

W. Scott Melvin, MD
Center for Minimally Invasive Surgery
The Ohio State University
Columbus, OH, USA

Mani Menon, MD, FACS
Department of Urology
Vattikuti Urology Institute
Detroit, MI, USA

James L. Mohler, MD
Department of Urologic Oncology
Roswell Park Cancer Institute
Buffalo, NY, USA

Vimal K. Narula, MD
Center for Minimally Invasive Surgery
The Ohio Sate University
Columbus, OH, USA

Barry Nuechterlein, MD
Department of Anesthesiology
The Ohio State University Medical Center
Columbus, OH, USA

Can Öbek, MD, FEBU
Department of Urology
Yeditepe University Hospital
Istanbul, Turkey

A. Pansadoro
Vincenzo Pansadoro Foundation
Rome, Italy

Sejal Dharia Patel, MD
Department of Obstetrics and Gynecology
The Ohio State University
Columbus, OH, USA

Vipul R. Patel, MD
Robotic and Minimally Invasive Urology Surgery
The Ohio State University
Columbus, OH, USA

James O. Peabody, MD
Vattikuti Urology Institute
Henry Ford Health System
Detroit, MI, USA

Thierry Piechaud, MD
Clinique St. Augustin
Bordeaux, France

Craig A. Peters, MD, FAAP, FACS
Department of Urology
University of Virginia
Charlottesville, VA, USA

Sandhya Rao, MD, MCh
Department of Urology
Weill Medical College of Cornell University
New York, NY, USA

Charles-Henry Rochat, MD
Clinique General Beaulieu
Geneva, Switzerland

Francois Rozet, MD
Department of Urology
L'Institute Mutualiste Montsouris
Paris, France

Laurent Salomon, MD
Urology Service CHU Henri Mondor
Créteil-Cedex, France

Richard C. Sarle, MD
Vattikuti Urology Institute
Henry Ford Health System
Detroit, MI, USA

Shikha Sharma, MD
Glickman Urological Institute
Cleveland Clinic
Garfield Heights, OH, USA

Alok Shrivastava, MD, MCh
Vattikuti Urology Institute
Henry Ford Health System
Detroit, MI, USA

Douglas W. Skarecky, BS
Department of Urology
University of California, Irvine Medical Centre
Orange, CA, USA

Joseph A. Smith Jr., MD
Department of Urologic Surgery
Vanderbilt University
Nashville, TN, USA

Atsushi Takenaka, MD, PhD
Department of Organs Therapeutics
Kobe University Graduate School of Medicine
Kobe, Japan

Ashutosh Tewari, MD, MCh
Brady Urology Department
New York Presbyterian Hospital/Weill Cornell Medical College
New York, NY, USA

Raju Thomas, MD, FACS, MHA
Department of Urology
Tulane University Health Sciences Centre
New Orleans, LA, USA

Guy Vallancien, MD
Department of Urology
L'Institute Mutualiste Montsouris
Paris, France

Christopher L. Yerington, MD
Department of Anesthesiology
The Ohio State University Medical Centre
Columbus, OH, USA

Gregg E. Zimmerman, MD
Department of Urologic Oncology
Roswell Park Cancer Institute
Buffalo, NY, USA

Craig D. Zippe, MD
Glickman Urological Institute at Marymount Hospital
Cleveland Clinic
Garfield Heights, OH, USA

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Robotic Urologic Surgery: An Introduction and Vision for the Future

Nicholas J. Hegarty and Inderbir S. Gill

1.1. Definition

Robots have been defined as "a reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks" by the Robot Institute of America. Websters' English dictionary describes robots as "an automatic apparatus or device that performs functions normally ascribed to humans or operates with what appears to be almost human intelligence." These definitions encompass three levels of functionality—the ability to perform defined maneuvers, the ability to perform such tasks in a preprogrammed order, and the ability to interpret and modify responses to commands, based on experience and learning.

1.2. A Brief History of Robotics

1.2.1. Early History

In 400 BC, the philosopher and mathematician Archytas of Tarentum built the first self-propelled flying device, *the pigeon*, a wooden bird driven by steam that could flap its wings and reportedly fly a distance of 200 feet.

In 250 BC, Ctesibius of Alexandria modified a clepsydra, or water clock, which until then had only been used to determine the end of a defined period of time, into a continuously working clock. This became the most accurate timepiece in the world and was not surpassed until the 17th century, when Christiaan Huygens introduced the pendulum to clock making.

In 1495 AD, Leonardo da Vinci designed a mechanized mannequin in the form of an armed knight. "Leonardo's Robot" became the model from which numerous performing mannequins were constructed as a form of entertainment in the Renaissance. Amongst the most famous of these were Gianello Toriano's mandolin-playing lady, built in 1540, and Pierre Jacquet-Droz's child, built in 1772.

In 1801, Joseph Jacquard constructed an automated loom, which was the first use of programmable machinery in industry. A punch card system was used to enter commands, akin to the punch cards used for computer programming in the 1960s and 1970s.

In 1898, Nikolas Tesla demonstrated the ability to command devices from a distance when he exhibited a radio-controlled boat in Madison Square Garden in New York City; however, the concept of robotics is one from the 20th and, now, 21st centuries.

1.2.2. Robotics in the Modern Era

The term *robot* was first coined by Karel Capek in the 1923 book *Rossum's Universal Robots*[1] and relates to the Czech word for slave labor, *robota*. In 1942, Isaac Assimov created the word *robotics,* describing the technology of robots, in his science fiction work *Runaround*.[2] He subsequently went on to formulate the rules of robotics in the novel *I, Robot*[3] and these have become central to many of the fictional works that have since emerged.

Some of the earliest practical uses of robotics have been by the military. During World War II, mine detectors on the front of U.S. tanks would automatically slow their progress each time a mine was encountered. The German forces developed bombs that could adjust their in-flight direction based on radar readings. It has, however, been only in the last half century that practical applications for robotics have expanded with the introduction of industrial robots.

The first modern industrial robots were manufactured by George Devol and Joe Engleberger in the early 1950s. Together they formed the company Unimation (universal automation) and created the Unimate, a multijointed industrial robot arm. The first of these were used to handle molten die castings in General Motors assembly lines. In 1978, Victor Scheinman developed the first truly flexible arm, known as the Programmable Universal Manipulation Arm (PUMA), and this quickly became the industry standard.

Though initially prohibitively expensive, the success in performing tasks considered unpleasant and, in many instances, dangerous to humans paved the way for the expansion of robots in industry. Other attributes of industrial robots include the capability of performing tasks ranging from those requiring tremendous strength to those requiring micrometer precision, as well as performing rapid maneuvers and repetitive tasks without the effects of fatigue or boredom. One shortcoming of industrial robots, however, has been their general restriction in mobility; the considerable bulk of many or the requirement to be mounted on platforms effectively limits their use to a single site and thus they do not have the versatility of other machinery or of personnel that can be moved between areas of work. Several companies have endeavored to create mobile robots. In 1983, Odetics introduced a six-legged vehicle capable of climbing over objects. This robot could lift almost six times its weight while stationary and more than twice its weight while mobile. Many more mobile robots have since been produced, but perhaps the two with the highest profile have been the Mars rovers: the rovers *Spirit* and *Opportunity* landed on Mars on January 3 and January 24, 2004, respectively, and at the time of this writing have spent more than two years exploring the planet's surface. In this time they have transmitted knowledge of planetary soil and minerals, and have provided evidence of the prior existence of water at or near the surface of the planet.

Experience with the significant setup costs of robots and robotic systems in industry provides an important lesson in fiscal responsibility: in the mid-1980s, expansion occurred in the manufacture and use of industrial robots, in many cases beyond their financial viability. This led to a lengthy period of recession in the robot industry, with production more recently being restored to a healthier level.

1.2.3. Surgical Robots in the Future

The most immediate advances in robotics are likely to come through incremental changes in currently available systems, while longer term advances will involve more radical design changes that involve miniaturization and changes of surgical approach, as well as integrating new and existing technologies into the operative arena.

1.3. Instrumentation

Although considerable progress has been achieved with robotic instrument design, tremendous potential exists for further improvements. Expansion is expected to continue in the range of robotic instruments available to match and eventually exceed the variety of currently available laparoscopic devices. This will reduce the requirement of the tableside assistant to perform basic tasks such as suction and clip application. With the probable emergence of robots with an increased number of arms, it is likely that the surgeon will have a greater number of instruments at his disposal at any given time, further reducing the need for surgical assistants.

1.4. Optics

The quality of image afforded the operating surgeon is one of the great attributes of the da Vinci® system (Intuitive Surgical Inc., Sunnyvale, CA). Continued improvement will occur in both optics and monitors enhancing the view for the operating surgeon and delivering a similar image to others in the operating room.

1.5. Robotic Arm Design

The inevitable reduction in the size of operating instruments will facilitate the development of smaller robotic arms and provide the opportunity to design operating rooms with the robot arms suspended from the ceiling akin to current anesthetic gas inflow systems. This would have a number of advantages, including freeing up space around the patient to improve access for anesthesia or surgical assistants. Without the need for docking of the robot, setup times would likely be reduced and adjustment of the operating table or the patient might be possible while maintaining the robot arms in position.

1.6. Console Design

Expanding the design of consoles to accommodate two or more operators would provide a number of potential benefits. As a teaching aid, dual consoles could be used to allow the trainer and trainee share the operation, with control of the instruments being changed as the stage of the operation or level of experience of the trainee would dictate. Consoles would not need to be in direct proximity to each other, allowing training to be performed even between institutions. Dual consoles would also increase the number of arms and thus the number of instruments that could be functional at any given time. This would permit both the principal surgeon and the assistant to operate at the robot console and lessen the need for tableside assistance. Finally, it would mean that a surgeon could potentially be available to supervise and participate in portions of operations in more than one operating room at a time.

1.7. Telecommunications

Improved communication systems and information transfer in the form of ISDN lines has facilitated the performance of procedures at great distances from the patient and the whole field of telepresence surgery. Further advances in this field will allow interaction between centers during more complex surgeries, providing clear real-time sound and vision. The incorporation of wireless technology will allow multiple systems to be linked, facilitating information transfer, surgical mentoring, and supervision.

1.8. Tactile Feedback

One obvious discrepancy that exists between robot-assisted and open surgery is the almost complete lack of tactile feedback afforded to the surgeon. It has been argued that the enhanced view obtained with robotics compensates for this, with tension in knot tying and plains of dissection becoming perceptible from visual cues. While this may be true to some extent, the incorporation of tactile sensation into the instrumentation is likely to enhance the overall surgical experience. Much effort is currently going into refining this technology, which for the present remains extremely expensive. Robotic systems do lend themselves to the use of other sensory inputs: integration of strain gauges into instrumentation could provide information on suture and tissue tension, intraoperative microscopy could be used as an aid to determining tumor margins or proximity to nerves or other vital structures, while intraoperative radiological imaging could provide the surgeon with real-time information on tumor location and alterations in the target surgery area as surgery progresses. Expanding the operative environment to include real-time imaging tools and other data will help to create a cockpit environment for the surgeon.

1.9. Access

Traditional access for minimally invasive abdominal surgery has been through the abdominal wall. Less invasive routes of access are currently being explored. Several procedures have already been described using a transgastric approach,[4] while a transvaginal approach in the female patient and other transenteric routes in both male and female patients would have less wound discomfort and contribute to shorter convalescence than abdominal incisions. Miniaturization of instruments will open up new portals of access, such as the vasculature and the urinary tract, with steerable operating catheters being capable of delivering complex diagnostic and interventional devices to their target area.

1.10. Miniaturization

The development of robots for intracorporeal use provides a number of challenges. As well as concerns of safety and reliability, units must be designed with their own power source and have mobility subject to external control, with all this in miniature. Such devices have already found a role in clinical practice. Examples include mobile microrobotic endoscopic cameras that provide diagnostic images while transiting the gastrointestinal tract under external joystick control. The scope for such devices to act as diagnostic and therapeutic tools is great; however, the field of nanotechnology (dealing in measurements of one billionth of a meter) is likely to take this to its extreme. The ability to incorporate devices at cellular and even subcellular levels holds tremendous potential for many areas of clinical practice; delivery of drugs and other therapeutic agents could be modified by nanosensors, while early detection of malignant and precancerous lesions and DNA sequencing and repair will greatly impact our capacity to cure disease.

1.11. Autonomy

While current robotic systems have concentrated on translating open surgical maneuvers into movements of the surgical arms, systems capable of performing surgical maneuvers autonomously would represent a significant advance. As in industry, the exact replication of technique as well as potential for increased speed would be advantageous, albeit with the understanding that the surgical environment is not as fixed as the production line. Imaging and preoperative planning of no-go areas such as the iliac vessels and obturator nerves during pelvic lymph node dissection could ensure a certain level of safety and these no-operation zones could be modified during the course of dissection, based on visual cues and progress of the operation. Incorporating artificial intelligence provides the potential for robots to plan, execute, and learn from the experience of performing portions of surgeries, or even entire surgeries. However, until this technology is safely in place, the skill and ingenuity of the surgeon will still be required to oversee surgery.

1.12. Conclusion

The concept of robots in surgery, formerly in the realm science fiction, is now a reality. For the most part, robots are used to translate operative maneuvers of the surgeon into a precise movement of the robotic arms. The establishment of systems that can safely replicate the complexities of surgery in a safe manner has been a tremendous achievement. Still, there are many areas in which current systems can be improved. However, the greatest advances are likely to be in facilitating the performance of feats that are currently not humanly possible. The goal of a thinking, learning operating robot capable of executing maneuvers at a cellular level is perhaps still some way off. Until then, robots will remain as a tool for the operating surgeon who must be mindful of their limitations, yet utilize the unique features they do provide in order to continue to improve patient care and outcomes.

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2

Robotic Surgical Systems

Vimal K. Narula and W. Scott Melvin

2.1. Introduction

Surgery has evolved from the 19th century through the introduction of ether anesthesia, principles of antisepsis, and the formalization of surgical training.[1] In the late 20th century, the introduction of laparoscopy and robotics has continued to evolve the practice of surgery. The computer revolution has affected all of our lives. Computers affect the surgeon's interaction with the patient and the mechanics of tissue manipulation.[2] At present time, a multitude of devices are available to assist, to interact, and to perform tasks in concert with the surgeon to complete the operation. The computer revolution compliments, and has added to, the development of robotic technology. This chapter will review the development of robotic surgical systems and instrumentation, the benefits they offer over conventional laparoscopic surgery, and the future of robotic technology.

2.2. Robotics in Surgery

The first surgical application was in a neurosurgical procedure in 1985. The Programmable Universal Manipulation Arm (PUMA) 560 was used to orient a needle for a brain biopsy under computerized tomography (CT) guidance.[3] This was discontinued due to safety issues. The Imperial College of England created a robotic system called PROBOT to assist in the transurethral resection of the prostate. In 1988, the first autonomous surgical procedure was performed by a robot. In this procedure, a three-dimensional (3D) model of the prostate was built, the resection area was outlined by the surgeon, trajectories of cutting were calculated by the robot, and, finally, the procedure was performed.[4,5] In 1992, International Business Machines (IBM) produced a robotic system to aid in orthopedic surgery. The ROBODOC was utilized to assist in drilling out a hole in the femur for total hip replacement.[6,7]

Concurrently, research in the area of robotic telepresent surgery was being conducted at the Stanford Research Institute, the National Aeronautics and Space Agency (NASA), and the Department of Defense. Telepresent surgery allowed a surgeon to operate at a distance from the operating room.[8] The original prototype was created for military purposes, and the robotic arms were designed to mount onto an armored vehicle to provide immediate operative care while en route from the battlefield to the medical base. However, Intuitive Surgical Inc. (Sunnyvale, CA). acquired the prototype from the military for commercial purposes. This gave birth to the da Vinci® robotic system, which was based on the concept of *immersive telepresence*, that is, the surgeon operates on the patient at a distance but feels that he is in the operating room. Simultaneously, another company, Computer Motion (Santa Barbara, CA), introduced the first laparoscopic camera holder: AESOP (Automated Endoscopic System for Optimal Positioning). They also went on to produce the Zeus® surgical system, which was based on the *integrated robotic system* concept, that is, the surgeon operates at a distance from the patient but is cognoscente of the distance.[9]

2.3. AESOP System

The first robot to be approved by the U.S. Food and Drug Administration (FDA) was AESOP 1000 in 1994. AESOP was the conception of Computer Motion and was one of the first tele-operated robots introduced for clinical use in surgery. Computer Motion was initially funded by a NASA research grant for the development of a robotic arm for the U.S. space program. This arm was later modified to become the first laparoscopic camera holder.[10] When it was first introduced, the robotic arm was controlled either manually or remotely with a foot switch or hand control.[11,12] By 1996, Computer Motion had progressed to a voice-controlled robot in AESOP 2000 and by 1998 to one with seven degrees of freedom with AESOP 3000.[13,14] The robot attached to the side of the surgical table and had a series of adapters that allowed it to grasp any rigid laparoscope (Figure 2.1).

Advantages of AESOP were reported by Kavoussi and colleagues,[15] who did a comparison of robotic versus human laparoscopic camera control. The study group consisted of 11 patients requiring bilateral procedures. Robotically controlled camera positioning was used on one side and the traditional handheld camera on the contralateral side. They found the robotically controlled arm to be steadier than the human hand with comparable operating times. This was true in animal studies as well.[16] Urologists at Johns Hopkins demonstrated the utility of AESOP in laparoscopic procedures.[17] These included nephrectomy, retroperitoneal lymph node sampling, varix ligation, pyleoplasty, Burch bladder suspension, pelvic lymph node dissection, orchipexy, uterolysis, and nephropexy. On comparing the robotic assistant to the traditional human assistants, there was no significant increase in the operating times, and AESOP proved to be once again a steadier camera platform.[18] In gynecology, Mettler and colleagues[19] used AESOP to perform 50 procedures, and found the operating times to be similar to those operations performed with traditional hand controls. This group further concluded that the voice-controlled AESOP worked faster and more efficiently than the older systems. All these studies validated the utility of the AESOP robotic system.

Figure 2.1. The AESOP system with robotic arm to hold the laparoscopic camera, which can be controlled by foot switch or voice control. (Reprinted with kind permission from Intuitive Surgical, Inc. www.davinciprostatectomy.com/images/aesop_images.zip and www.davinciprostatectomy.com/images/zeus_images.zip by Alexis Morgan, Sunnyvale, CA, USA. January 2007.)

AESOP was the first to promote the idea of solo laparoscopic surgery. Geis and colleagues[20] used AESOP to perform and complete 24 solo-surgeon laparoscopic inguinal hernia repairs, cholecystectomies, and Nissen fundoplications. In Antwerp, Belgium and Catalina, Italy, AESOP was utilized in performing laparoscopic adrenalectomies.[21,22] The conclusion of both the groups was that AESOP was a stable camera platform that provided a constant video image to complete the operation. Meanwhile, in the United States, Ballantyne and colleagues[23] documented the ability of AESOP to facilitate solo-surgeon laparoscopic colectomies. They compared 14 robot-assisted laparoscopic colectomies performed in 2000 with 11 laparoscopic colectomies done in 1999. All the operations were done for benign disease and there was not a statistically significant difference in the operating times between the groups. Most of the procedures were performed with the three-trocar technique, without the help of a surgical assistant. The only time a fourth trocar was placed was when there was need for surgical assistance to perform lysis of adhesions. These studies demonstrated the feasibility of the solo laparoscopic surgery concept.

AESOP ushered laparoscopic surgery into an era of robot-assisted surgery. It had reliably replaced the human camera holder and provided a stable camera platform to perform and complete various laparoscopic procedures across the surgical subspecialties. By 1999, over 80,000 surgical procedures had been performed utilizing AESOP technology.

2.4. Telerobotic Surgery

The next step in the evolution of robotic surgery was telerobotic or telepresence surgery. The concept behind these operations is that the surgeon sits at a computer console and the computer translates the hand movements of the surgeon into motions of the robotic instruments. The surgical telerobot is positioned at the side of the patient and it is able to hold the camera and manipulate two or more instruments.[24] The surgeon and the console are at a remote site. The surgeon acts as the "master" and the robot as the "slave."[25]

The end result allows a surgeon from a remote site (aircraft carrier) to operate on a distant patient (injured soldier on the battlefield).[26] This was first demonstrated in 1991.[27] There currently are two commercially available telerobotic systems: Zeus® and the da Vinci® surgical system.

2.5. Zeus System

Computer Motion developed the Zeus® telerobotic system in the 1990s. AESOP was used as the foundation for Zeus®. The Zeus® system had two subsystems: the surgeon side and the patient side. The surgeon's side subsystem consisted of a console that had a video monitor and two handles that controlled the robotic arms. The surgical instruments were held by the robotic arms. The console could be placed anywhere in the operating room. The patient side subsystem consisted of three robotic arms that were attached to the table. These units were independent of each other (Figure 2.2).

Figure 2.2. The Zeus® system, showing the patient side subsystem consisting of three robotic arms that are attached to the table. (Reprinted with kind permission from Intuitive Surgical, Inc. www.davinciprostatectomy.com/images/aesop_images.zip and www.davinciprostatectomy.com/images/zeus_images.zip by Alexis Morgan, Sunnyvale, CA, USA. January 2007.)

Later, the controls were designed in a more ergonomic fashion. The AESOP voice-controlled robot was used alongside the Zeus® as the camera holder for the operations. A computer kept track of the tip of the instruments and the camera in a 3D environment. It also translated the motions of the surgeon to identical robotic movements.

Imaging for the Zeus® system was done by the Karl Storz system (Karl Storz Endoscopy, Santa Barbara, CA). The mechanics to create this 3D image were quite interesting. Separate right and left video cameras visualized the operative field. Each image was broadcast at 30 frames per second and a computer merged the two to make it 60 frames per second. The broadcasts were alternated between the left and the right camera. The monitor had an active matrix feature that allowed the matrix to alternate between a clockwise and counterclockwise filter. The surgeon wore special glasses that had a right lens that was a clockwise polarizing filter and the left lens was a counterclockwise polarizing filter. This allowed the surgeon to view the image of the video monitor in 3D.[28]

Zeus® was primarily designed to be utilized in cardiac surgery [e.g., coronary artery bypass graft (CABG)], and later was applied to the other surgical subspecialties, such as general surgery, gynecology, and urology.[29] Most of the clinical studies focused on cardiac surgery, with the most advanced procedure being the harvest of the internal mammary artery (IMA) and the performing of CABG. Boyd and colleagues, in London, Ontario, Canada, demonstrated the feasibility of harvesting IMAs.[30,31] Zeus® successfully harvested IMA in 19 patients using a closed chest, three-trocar technique. Following this, initial reports of performing CABG in animal models and cadavers were underway.[32,33] In 1999, Reichenspurner and colleagues reported the first successful CABG surgeries using the Zeus® system in two patients.[34] The surgeons harvested the IMA using endoscopic techniques and then anastomosed the IMA to the left anterior descending artery via the three-trocar technique. The heart was arrested using an endovascular cardiopulmonary bypass system (Heartport Port Access Systems Inc., Redwood City, CA). Over the next year this same group went on to successfully perform closed chest, off-pump CABG in three patients.[35] Using Zeus®, they subsequently performed 10 more CABGs.[36] The results of this study were that the anastomoses were technically satisfactory (as demonstrated by angiography) and the median operative time was acceptable. These studies paved the way for the rest of the cardiac community to consider the clinical possibility and already proven safety of robotic-assisted surgery. Other disciplines followed suit, using robotic-assisted surgery for tubal ligations to pelvic lymph node dissection for prostate cancer.

However, Zeus® had its limitations. The sheer magnitude of the instruments created logistical problems in the operating room. Misplacement of the trocars caused collision of the robotic arms during the operation. Zeus® did not provide tactile feedback and the surgeon had to rely on visual cues. The instrumentation lacked intra-abdominal articulation and had only six degrees of freedom. The 3D imaging feature was its main disadvantage. The surgeon has to use the specific glasses that allowed the two-dimensional (2D) monitor output to be viewed in the 3D environment. The image was blurred without the glasses and in some cases caused the surgeon or the assistants to have motion sickness. The basic difference between Zeus® and the other telerobotic surgical system was that it was developed to create an integrated robotic surgical environment and not as an immersive intuitive interface.[37] This allowed Zeus® to function only as a surgical assistant and not as the operating surgeon.

In spite of the obstacles Zeus® faced in its future, it is credited with all of the original human and animal studies performed to establish the efficacy and feasibility of robotic surgery. However, in 2003, Intuitive Surgical purchased Computer Motion, thus ending the production of Zeus®.[37]

2.6. da Vinci® Surgical System

This robotic surgical system was based on the concept of *immersive intuitive interface*. The system was based on three mechanisms[38] (Figure 2.3):

1. A master/slave, software driven system that provides intuitive control of laparoscopic instruments with seven degrees of surgical freedom.
2. A stereoscopic vision system displayed in immersive format.
3. A system consisting of redundant sensors to make the operation safe.

The initial prototype utilized a traditional stereo endoscope; however, in 1999, with FDA approval, binocular endoscopic vision was introduced by Intuitive Surgical Inc. This was the da Vinci 2000 and this system consisted of the following components.

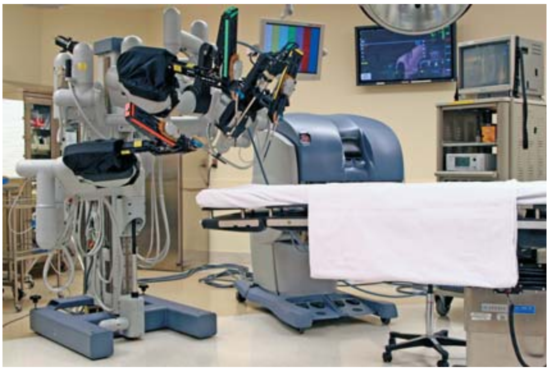

FIGURE 2.3. Three components of the da Vinci® robotic system: console, surgical cart, and video cart.

FIGURE 2.4. Surgeon at the console and the robotic operating room.

FIGURE 2.6. The robotic telescope, consisting of two 5-mm scopes.

2.6.1. Console

The surgeon is seated in an ergonomically comfortable position at the console. This is placed in the same room as the patient, at a remote location (Figure 2.4). In the United States, the FDA requires the console to be in the same room as the patient. The console consists of a stereo viewer that is controlled by an infrared sensor. The system is activated when the surgeon's head is in the console and the arms come to life. If the head is removed, immediate deactivation occurs, and the robotic arms are locked in place. This is a very useful safety mechanism. The surgeon's hands are inserted in the free-moving finger controls. These controls convert the movements of the fingertips and wrist into electrical signals (Figure 2.5). These are then translated to computer commands that allow the robot to mirror the movements in the operative field. The control panel is able to control 3D viewing, the adjustment of the console height, the camera control, and has the ability to select between a 0° or 30° viewing scope (Figure 2.6). It also allows the surgeon to toggle between the arms of the robot. All these tasks can be accomplished with the hand and foot pedal controls on the console. The console is connected to the video and surgical component of the robot via cables.

FIGURE 2.5. Surgeon's hands in the finger controls, which translate the finger and wrist movements into electrical signals.

2.6.2. Video

The da Vinci® truly offers a 3D imaging system that is similar to looking through field binoculars. The video cart consists of two video camera control boxes, two light sources, and a synchronizer. The telescope for this system is 12 mm in diameter and contains two 5-mm scopes. The images are cast on two different cathode ray tube (CRT) screens and the synchronized. This allows mirrors to reflect the images of the CRT to the binocular viewer in the console. The right and left images remain separate due to the two 5-mm scopes and, thus, the binocular feature is accomplished successfully.

2.6.3. Surgical Component

This component consists of either three or four arms, depending on the generation of the robot (Figure 2.7). Surgical instruments are attached to the robotic arms via adapters, which use an 8-mm

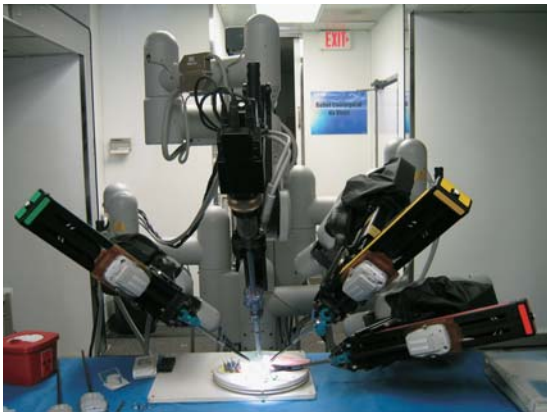

Figure 2.7. Three-armed da Vinci® robotic system.

Figure 2.9. Different robotic instruments like dissectors, graspers, and scissors. The operational life of each instrument is roughly 10 cases.

da Vinci®–specific port. The central robotic arm houses the 12-mm viewing scope, while the outer arms grasp surgical instruments. These instruments are articulated at the wrist and have seven degrees of freedom and 2° of axial rotation (Figure 2.8). These 8-mm da Vinci®–specific ports have adapters that allow the use of 5-mm instruments as well. The life of the instruments is 10 cases, after which the system will not allow the operational use of the instrument (Figure 2.9). Even though the instruments are reusable, this feature guarantees quality control (i.e., fine motor movements) for the procedures. The robot is positioned alongside the patient table.

Validation of the da Vinci system, like Zeus®, began with cardiac surgery. Carpentier and colleagues reported the first successful use of the da Vinci® surgical system for closed chest CABG.[39] The Leipzig group used the da Vinci® system in a progressive manner.[40] Initially, they used the da Vinci® system to harvest 81 left internal mammary arteries (LIMA). In the next phase, they used the da Vinci® system to sew 15 LIMA to left anterior descending arteries (LAD) using a median sternotomy incision. The last two phases used the robot to construct LIMA-to-LAD bypass grafts on an arrested heart with closed chest technique, followed by performing the same operation on the beating heart. In January 2002, Dr. Michael Argenziano of New York Presbyterian Hospital performed the first successful closed chest CABG using the da Vinci® system in the United States. Clinical experience for mitral valve repair was also gaining ground. The Leipzig group successfully performed mitral valve repairs on 13 patients,[41] while Chitwood and colleagues headed the mitral valve trial at the East Carolina University in Greenville, North Carolina.[42]

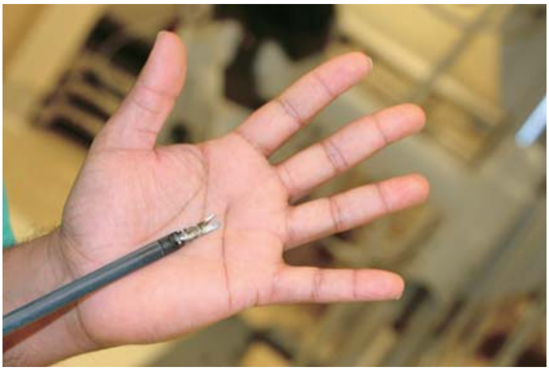

Figure 2.8. The robotic instrument with articulation at the wrist and seven degrees of freedom and 2° of axial rotation.

Abdominal surgery was not far behind in the use of the da Vinci® system for laparoscopic operations. Cadiere and colleagues were the first to report the successful use of the da Vinci prototype to perform a laparoscopic cholecystectomy in 1997.[43] Cadiere further went on to perform laparoscopic gastric bypass,[44] Nissen fundoplication,[45,46] and fallopian tube anastomosis[47] using this telerobotic technology. Other groups had similar success with the robot for a variety of abdominal operations. The group from East Carolina School of Medicine reported the successful use of the robot for laparoscopic cholecystectomy, Nissen fundoplication, and splenectomy.[48,49] At The Ohio State University, Melvin and colleagues performed a variety of foregut operations using the da Vinci® system. These included laparoscopic pancreatectomy, Nissen fundoplication, Heller myotomy, and laparoscopic esophagectomy.[50,51] In all these studies, the operative times of the robot were significantly higher that the standard laparoscopic technique. This was the early part of the learning curve that was still being defined. In Italy, Ceconni and colleagues showed that after 20 robot-assisted laparoscopic cholecystectomies, the operative time dropped from 103 min for the first 20 cases to 70 min for the next 19 cases.[52] The time studies suggested that experienced laparoscopic surgeons rapidly gained facility with this telerobotic technology.[53] Most of these reports were presented at the Society of American Gastrointestinal Surgeons (SAGES) meeting in April 2001. These studies showed that telerobotic gastrointestinal surgery could be performed safely.[10]

2.7. Advantages of Robotic Technology

Telerobotic technology has come a long way from 1994 with AESOP to the da Vinci® S that was introduced in 2006. Many improvements have been made not only in the instrumentation, but also in the video imaging and the design of telerobotic technology. The da Vinci® system provides the surgeon with 3D vision that adds to precision and dexterity while performing the operation. The *immersive telerobotic environment* simulates the environment of open surgery. This environment, when combined with 3D vision, makes for truly intuitive hand/eye coordination and excellent depth perception during suturing and tissue handling.[54] The robotic arms are articulated at the wrist, which allows for a total of seven degrees of freedom, including four movements found in traditional laparoscopy, and two endocorporeal movements in addition to the grip movement. This feature allows the da Vinci® system to have intra-abdominal articulation in seven different planes. In addition, the da Vinci® system has tremor filtration and motion scaling features that makes it ideal for complex laparoscopic movements like intracorporeal suturing and micromovements in an anatomically confined space.[9]

2.8. Telepresence Surgery

The first telepresence procedure was performed in 1998. Bauer and colleagues[55] performed a percutaneous renal access on a patient in Rome, Italy, while the surgeon was in the United States. In 2001, Marescaux and colleagues[56] performed a robotically assisted laparoscopic cholecystectomy on a patient in Strasburg while in New York. In 2004, Mehran Anvari was involved in performing telepresence surgery using robotic technology on the undersea NASA habitat Aquarius. Anvari successfully guided the crew of NEEMO 7, stationed on Aquarius in the Florida Keys, through simulated surgeries including a cholecystectomy and suturing of arteries, from Ontario, Canada. This opened the possibilities of telepresence robotic surgery both at sea and in space.[57] The upcoming NEEMO 9 mission in 2006 will continue further research in this area. The key to the future of telepresence surgery is the connections that allow the signal to be transmitted and translated by the robot performing the operation. To operate over long distances, the current technology utilized is ISDN and the Internet, which brings up issues of consistency and reliability.[9] The other crucial factor in the success of this technology is the speed of the connection that transfers the information from the operator to the robot. The lag time from the operator to the execution of the task ideally should be less than 200 ms.[58] The delay can be minimized with direct links such as a transatlantic fiber optic cable. However, using satellites to do the digital transmission causes long delays because of the distance being too great. Future research in this area is paramount to the success of this novel concept. Success of this technology may someday meet the needs of patients in remote and medically underserved regions and the soldiers in the battlefield.

Telepresence involves significant ethical issues as well. Patient privacy and responsibility for the care of the patient are important issues. The accountability factor that involves the surgeon at the bedside versus the surgeon in a remote location will have to be addressed prior to widespread use of this technology. Licensure and credentialing in different states in the United States by itself is an issue, not to mention the complexity involved in performing operations abroad.

2.9. Future Designs

There is extensive ongoing research to improve on the current robotic surgical systems. These areas include utilizing miniaturized motors to decrease the size of the robotic tower and mounting the robotic tower on the ceiling or wall to increase the access points to the patient. The console viewer would have the ability to display real-time images, along with non–real-time images of the patient. This would allow the surgeon to monitor the blood supply of the target organ by real-time ultrasound, and pinpoint the lesion via real-time magnetic resonance imaging (MRI)/CT images, which will be superimposed onto the operative image.[9]

The concept of a mentoring console is also being researched by Intuitive Surgical Inc. This would allow the master controls to be toggled between the mentor and the trainee in the operation to facilitate teaching in the similar fashion as traditional open surgery.[9] We already have surgical simulators which have tactile feedback. ProMIS is one such device that has the software to give tactile feedback during a virtual reality training session. Haptica (Dublin, Ireland) has developed ProMIS HALC, a breakthrough in surgical training. ProMIS HALC is a new augmented reality simulator for hand-assisted laparoscopic colectomy (HALC). This training tool, through the combination of real tactile feedback and virtual reality, gives the surgeon an unparalleled opportunity to practice, step by step, a hand-assisted laparoscopic sigmoid resection.[59] The next step is have a robotic validated training curriculum for residents and surgeons. A pilot study performed at The Ohio State University looked at utilizing the ProMIS technology as an objective skills assessment system for robotic skills training.[60] ProMIS simulator technology was indeed useful in plotting the learning curves for robotic skills training. Once this technology is successfully incorporated with the robotic surgical system, it could change the way we learn, teach, and practice the art of surgery.

2.10. Conclusion

What started as a game, a gimmick for the amusement for the royalty, has now becoming the technology that society relies on in all different arenas. The use of robotics is widespread in computers, the automotive industry, ocean and space exploration, entertainment, and medicine. Robotics in the field of surgery is growing at an exponential pace, especially with its applications in conjunction with minimally invasive surgery. The use of telepresence and telementoring in the field of surgery is growing and its applications are endless. For the first time, the saying “it’s a small world after all” holds true. Robotic technology may have started as a thing in our past, but it is definitely an integral part of our future.

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3

Multispeciality Applications of Robotic Technology

Geoffrey N. Box and Michael Gong

A paradigm change in the approach to the surgical patient began in 1987 when Mouret performed the first laparoscopic cholecystectomy.[1] Since then, laparoscopic minimally invasive surgery has been utilized to perform a wide variety of procedures that encompass many surgical specialties. However, limitations in the instrumentation prevented the widespread application of laparoscopic techniques for more complex and reconstructive procedures. Intuitive Surgical Inc. (Sunnyvale, CA) and Computer Motion (Santa Barbara, CA) were the initial companies that developed the technology for robot-assisted surgery, attempting to overcome the limitations of traditional laparoscopic techniques. The first robots were utilized merely as laparoscopic assistants; however, with advancing technology, robots became more widely utilized as critical components of minimally invasive procedures. Contemporary robotic systems offer unparalleled magnified three-dimensional (3D) vision and the robotic instruments are more precise and dexterous than the human hand.

This chapter will highlight the current and potential future applications of robotic surgery in most of the surgical subspecialties outside of urology, including cardiothoracic surgery, general surgery, and neurosurgery.

3.1. Cardiothoracic Surgery

Robot-assisted surgery was originally pioneered for cardiothoracic procedures because traditional minimally invasive instruments and techniques were inadequate to perform safe and efficient cardiac surgery. Robot-assisted surgery offered superior precision, visualization, and fine instrument movement than traditional laparoscopic techniques.

The development of port-access technology in the mid-1990s was critical to the clinical application of robot-assisted cardiac surgery.[2] This system provided a technique for endovascular cardiopulomonary bypass and cardioplegic arrest. The port-access system consists of an endo-aortic clamp, an endopulmonary vent, and femoral vessel bypass. The endo-aortic clamp is a triple lumen catheter with an inflatable intraaortic balloon at the tip that occludes the ascending aorta. Cardioplegic solution can be applied through the central lumen of this catheter, achieving arrest with no cannulae in the operative field.[3] The central lumen also serves as an aortic root vent used to release pressure following cardioplegic delivery. The balloon is positioned with fluoroscopy or transesophageal echocardiography. The endopulmonary vent is a pulmonary artery catheter that is placed through the jugular vein to assist with ventricular decompression. The third lumen of the catheter serves as an aortic root pressure monitor. Finally, cardiopulmonary bypass is achieved via femoral catheters. Many cardiac surgeries, with the exception of aortic valve surgery, can be performed with this technology.

The first robot-assisted surgery was performed by Carpentier in Paris in May 1998,[4] and Loulmet performed the first coronary artery bypass graft (CABG) procedure without performing a median sternotomy later that same year.[5] Ultimately, totally endoscopic CABG on a beating heart was performed in 2001.[6]

3.1.1. Coronary Revascularization

The most frequently performed robotic cardiothoracic procedure is the revascularization of the left anterior descending coronary artery (LAD) with the left internal mammary artery (LIMA). This is a technically demanding procedure with a steep learning curve. It must also compete with other minimally invasive techniques that take less time, and are not as dependent on technology, such as minimally invasive direct coronary artery bypass grafting (MIDCAB). Total endoscopic robot-assisted revascularization of the LAD on a beating heart was first performed in 2001.[6] This technique uses an endoscopic epicardial stabilizer that combines both pressure and suction to stabilize and visualize a target vessel adequate for anastomosis. The main limitation of total endoscopic revascularization is the time to perform the anastomosis, which takes three to four times longer than conventional CABG surgery. This is important because the myocardium does not tolerate ischemia during endoscopic surgery as well as after a sternotomy.[3]

There is an extensive experience reported in the literature with the Zeus® robotic system (Computer Motion), however it is no longer being manufactured, so this review will focus on reports utilizing the da Vinci® robotic system (Intuitive Surgical Inc.). Three groups have large experiences with coronary artery revascularization using the da Vinci® system.[7–9] Mohr reported results on 131 patients who underwent varying degrees of robot-assisted CABG surgery. They used a stepwise approach, initially only taking down the LIMA with the robot-assisted surgery; the LIMA to LAD anastomosis was then performed via a standard sternotomy. The role of robot-assisted surgery was expanded to perform a total endoscopic approach first on an arrested heart, and ultimately on a beating heart.[9] At three months follow-up, 95% of the grafts were patent on angiography. The conversion rate for total endoscopic procedures can be significant. As with other reported laparoscopic techniques, there appeared to be a learning curve that improved with experience. Reported rates of open conversion are as high as 30%,[8] although Dogan's study reported their conversion rate decreased from 22% in the first 25 patients to 5% in the last 20 patients.[9] The experiences of these centers have demonstrated the efficacy and safety of robot-assisted coronary artery revascularization. Notably, most of the patients in these reports had single vessel disease. According to Diodato and Damiano, totally endoscopic CABG is reserved for highly selected patients with limited disease.[10] Widespread application awaits the development of more sophisticated robotic systems, improved target site stabilizing devices, and technologies to increase the intrathoracic space and improve visualization.[10]

3.1.2. Cardiac Valve Replacement

The first robot-assisted endoscopic mitral valve (MV) repair was done in 1998.[4] The first MV repair in North America was performed in January 1999.[11] A large multicenter prospective phase II U.S. Food and Drug Administration (FDA) trial was completed in 2002 and published in June 2005.[12] This trial provided data for the FDA's approval of the da Vinci® system for mitral valve surgery in November 2002. One hundred and twelve patients at 10 centers underwent mitral valve replacement with the da Vinci® robot for moderate-to-severe mitral valve regurgitation. A 4-cm right minithoracotomy incision and two robotic arm ports were used to perform the procedure. Mean operating room (OR) time was 266 min (range, 150–463 min) with an mean time on the da Vinci® robot console of 78 min. Nine (8%) patients had at least grade 2 regurgitation on trans-esophageal echocardiogram (TEE) at the one month follow-up and six (5.4%) required reoperations. No deaths, strokes, or device related complications were reported. One center in the FDA study has now completed 150 robotic mitral valve repairs with four (2.7%) patients requiring re-operation and two deaths (1.3%).[13] Patient selection is paramount, as multiple contraindications exist, including previous right-sided thoracotomy, severely calcified valve, and the need for concomitant cardiac procedures. Currently, robotic mitral valve surgery has proven to be safe and efficacious, however, longer follow-up is needed to determine its equivalency to the traditional open surgery via a median sternotomy.

3.2. General Surgery

General surgery encompasses a broad field and thus the individual procedures that are performed with robot assistance will be discussed. Most transabdominal procedures that can be performed with traditional laparoscopic techniques have been performed with robot-assisted techniques. What remains to be seen is whether utilizing the robotic assistance truly offers any advantage to traditional laparoscopic techniques.

3.2.1. Antireflux Surgery (Nissen Fundoplication)

Laparoscopic antireflux surgery has become the standard treatment for refractory gastroesophageal reflux disease (GERD). Two randomized controlled trials have compared robot-assisted and traditional laparoscopic Nissen fundoplication procedures. Cadiere and colleagues reported on 21 patients randomized to traditional versus robot-assisted surgery.[14] Melvin and colleagues then reported on 40 patients who underwent the same randomization.[15] Both studies showed no differences in the success or complication rates and also demonstrated the safety of this procedure. However, both institutions reported significantly longer operative times (76 min vs. 52 min[14] and 141 min vs. 97 min[15]). The larger study showed a significant difference in the use of antisecretory medications, however, the authors concluded this could not be attributed to the use of the robot. Hanly and Talamini have suggested robot-assistance may offer a technically better repair in patients who also have a significant hiatal hernia.[16] Generally robot-assisted antireflux surgery has proven to be safe and effective, but currently appears to offer no obvious advantage to traditional laparoscopic techniques.

3.2.2. Heller Myotomy

The standard treatment of achalasia of the esophagus is a Heller myotomy procedure. More recently, minimally invasive techniques have been utilized to decrease the morbidity of the procedure. Melvin reported the first robot-assisted Heller myotomy in 2001.[17] Since then several series have been reported demonstrating the safety and efficacy of this procedure.[18,19] Esophageal perforation is a potentially devastating complication of this procedure, and has been reported in up to 15% of laparoscopic cases.[20] A recent large series of 104 patients who underwent robot-assisted Heller myotomy with partial fundoplication was reported.[24] Patients were followed prospectively and all patients reported improvement in their symptoms. Eight minor complications were reported, but, importantly, there were no intraoperative esophageal perforations. As with most robot-assisted procedures, the operative time decreased significantly from the first two years (162 min) to the last year (113 min). The authors concluded that the enhancement in fine motor control, magnified 3D visualization, and motion scaling offered by the robotic systems gives a clear advantage over standard laparoscopic techniques.

3.2.3. Esophagectomy

Esophagectomy via an open approach is associated with significant morbidity. A transhiatal (abdominal/cervical) or Ivor–Lewis (abdominal/thoracic) approach is typically used. The transhiatal approach has reported a slightly improved in-hospital mortality rate (5.7% vs. 9.2%), decreased rate of anastomotic leaks (7.2% vs. 13.6%), and decreased pulmonary complications when avoiding a thoracotomy.[22] A minimally invasive approach to esophagectomy was first described in the early 1990s and a recent large series of 222 patients showed improved outcomes with a mortality rate of 1.7% and a mean hospital stay of seven days.[23] Limitations in laparoscopic instrumentation lead to attempts to utilize a robot-assisted approach. Melvin reported one of the first cases of a robot-assisted esophagectomy using a modified Ivor–Lewis technique in 2002.[24] Subsequent publications have been sparse with the largest series being reported by Espat.[25] They called the procedure robotically assisted transhiatal total esophagectomy (RATE). The procedure is started via a transabdominal approach using conventional laparoscopy for gastric mobilization. Then the da Vinci® robot is docked and robot assistance is used to carefully dissect to the level of the carina. Next, a cervical incision is made to complete the proximal mobilization and the re-anastomosis. Espat's series consists of 15 patients with high grade dysplasia who underwent the RATE procedure. The average operating room time was 274 min with the average estimated blood loss of 53 mL. All patients were extubated in the operating room with an average intensive care unit stay of one day. There was no perioperative mortality. The safety of this procedure has been established; however, the oncologic equivalence to open surgery has yet to be established. Prospective randomized trials are needed to demonstrate efficacy and until this data is obtained, the effectiveness of the RATE procedure remains to be determined.

3.2.4. Bariatric Surgery

Obesity continues to be one of today's greatest health problems, and minimally invasive techniques are widely utilized in contemporary bariatric surgery. The first robot-assisted gastric banding was reported in 1999,[26] and the first robot-assisted gastric bypass was described in 2000.[27] In a recent survey, only 11 surgeons in the United States were performing robot-assisted bariatric surgery.[28] In this survey, 107 cases were reported with favorable results. One of the reporting institutions described a significant decrease in OR time with more experience (312 min vs. 201 min). Subsequently, a single institution series of 110 patients also reported acceptable results.[29] Neither series reported any postoperative leaks. The reported benefit of robot-assisted Roux-en-Y gastric bypass procedure is the ability to perform the gastrojejunostomy with greater precision. Moser and Horgan believe this type of anastomosis has the best chance to decrease the risk of leak and/or stricture.[30] Stapled anastomoses have leakage and stricture rates of 1% to 3% and 9% to 31%, respectively,[31,32] whereas in the 217 robot-assisted cases described above, there were no reported leaks and only five (2.3%) strictures.[30] Several groups are currently collecting prospective data that will address the degree of benefit robot-assisted procedures may have in bariatric surgery.

3.2.5. Cholecystectomy

Robot-assisted cholecystectomy was one of the procedures performed in phase I trials to achieve FDA approval for robot-assisted surgery. When compared to standard laparoscopic techniques, several series have documented the equivalency with regard to clinical outcomes, but robot-assisted procedures have significantly longer operating times. A recent study reported on a randomized trial of robot-assisted (Zeus®) cholecystectomy (20) and conventional laparoscopic cholecystectomy (20).[29] Operating room times were 105 min in the robot group compared to 79 min in the laparoscopic group. No complications occurred in either group. To date, no benefit to performing robot-assisted cholecystectomy has been proven, however, some theoretical advantages have been proposed. The rate of common bile duct injuries is documented to be higher in the standard laparoscopic cholecystectomy technique.[33] Theoretically, robot-assisted surgery, with improved visualization and dexterity, could translate into a reduction in this type of serious complication, however, this requires further study. In a review of robot-assisted abdominal surgery, Hanley and Talamini have suggested robot-assisted cholecystectomy is likely to remain a very appropriate "practice" operation for general surgeons entering the realm of robotic-assisted surgery.[16]

3.2.6. Colectomy

The first robot-assisted colectomy was completed in 2001.[34] The three primary transabdominal rectal operations, low anterior resection, abdominoperineal resection, and rectopexy, have all been performed with the da Vinci® robot.[35] Many reports of robot-assisted colon surgery exist, and two series specifically compared robot-assisted surgical technique to traditional laparoscopic approach.[36,37] Both reported no difference in outcomes or morbidity. As expected, both series reported a slightly longer total OR time in the robot-assisted procedures. D'Annibale reported on 106 patients (53 in the robotic and 53 in the conventional groups) who underwent a variety of colorectal surgery. Operating room times were similar for both groups; 240 min in the robotic group and 222 min in the laparoscopic group.[37] Multi-abdominal quadrant surgery often required in colon surgery is a drawback of robot-assisted colon surgery because additional ports are typically necessary and occasional repositioning of the robot is required. These drawbacks can be overcome in some situations by mobilizing the left colon with traditional laparoscopic techniques before docking the robot. Robot-assisted surgery may prove to be advantageous for surgeries that are primarily in the pelvis, such as an abdominoperineal resection where the only large incision would be in the perineum.[35] Rectopexy for rectal prolapse has been performed with robot-assistance with excellent results.[38]

3.3. Neurosurgery

Neurosurgery is a subspecialty in which robot-assisted techniques could provide significant advantages. The brain is an organ uniquely suitable given its symmetric confinement within a rigid structure and extremely precise surgical maneuvers to avoid potential damage are absolutely required.[39]

Neurosurgery was one of the first specialties that attempted to incorporate robotics into their armamentarium. The Programmable Universal Machine for Assembly (PUMA) was the first surgical application of any robot that took place during a neurosurgical procedure in 1985.[40] The PUMA was an industrial robot used to hold and manipulate a biopsy cannula, or to provide surgical retraction. This was never widely accepted into the neurosurgical community in part because it lacked proper safety features.[41] Other robots utilized in neurosurgery include NeuroMate (Integrated Surgical Systems, Sacramento, CA), Evolution 1 (Universal Robotics System Schwerin, Germany), Cyberknife (Accuray Inc., Sunneyvale, CA), Robot-Assisted Microsurgery System ([RAMS], NASA, Washington, DC), Robo-Sim and NeuRobot (IUL Soft Warehouse AG, Holzkirchen, Germany). The neurosurgical robots that have been used clinically have only been able to perform stereotaxy, endoscopy, or brain retraction.[42] RAMS was developed by NASA and is a surgical manipulator with a slave arm mounted on a cylindrical base. This system has the potential to enhance various types of microsurgery, but only feasibility studies in animals have been performed.[43]

3.3.1. Project neuroArm

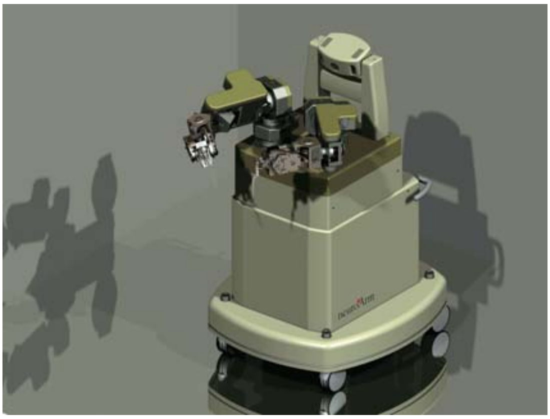

Figure 3.1. neuroArm base. (Reprinted with kind permission of Alexander Greer, Seaman Family MR Research Centre, Foothills Medical Centre, Canada.)

The state-of-the-art development in neurosurgical robotic surgery is Project neuroArm. This is a $30 million joint venture between the Calgary Health Region and the University of Calgary, lead by Dr. Garnette Sutherland. They have partnered with MD Robotics, the company who designed the robotic instruments for the Space Shuttle and the International Space Station. This system uses a master–slave setup that is compatible with real-time magnetic resonance (MR) imaging, and will be the first image-guided, MR-compatible surgical robot. The system consists of a surgical robot, a main controller, and a surgical workstation. The surgical robot has two arms, each with eight degrees of freedom, and small enough to operate in the confines of a MR magnet (Figure 3.1).[42] The surgical workstation has hand controllers for the robotic arms, and three displays (Figure 3.2).

Figure 3.2. neuroArm workstation. (Reprinted with kind permission of Alexander Greer, Seaman Family MR Research Centre, Foothills Medical Centre, Canada.)

The video display shows a 3D stereoscopic view of the surgical site provided by binocular video cameras. The MRI display shows real-time virtual tool position superimposed on the MR images. This would provide the opportunity for true MR image-guided surgery. The third display shows the system data and control settings. Some unique features of the neuroArm include the ability to set virtual boundaries to prevent inadvertent injury, haptic feedback based on three degrees of freedom optical force sensor system, among several other sophisticated safety features. The system will also have virtual surgery capabilities to serve as a simulator for surgeons in training. This robot is accurate to 30 microns, while the accuracy for a trained surgeon is estimated at only a millimeter. The design of neuroArm is complete and now manipulators are under construction for evaluation in phantom, animal, cadaver, and, eventually, human studies.

3.4. Orthopedic Surgery

Robots have been utilized in orthopedic surgery in an attempt to take advantage of the precision and reproducibility for joint replacement. The ROBODOC/ORTHODOC system is used to mill out the hole in the femur before hip replacement surgery. This robot was developed in the early 1990s and is not available for use in the United States, but is utilized in Europe. The ROBODOC is the surgical robot, and the ORTHODOC is the preoperative planning workstation. This system can be used to perform primary and revision hip replacement surgery and total knee replacement. The ORTHODOC workstation uses the patient's preoperative computerized tomography (CT) scan to precisely plan and actually simulate the surgical procedure. The preoperative plan is selected and the data is sent to the ROBODOC for implementation. A randomized controlled trial comparing ROBODOC and conventional hip replacement in 120 patients was published in 1998.[44] No difference in Harris hip scores or outcome questionnaires was seen. Operating room time and estimated blood loss was worse in the ROBODOC group, however, postoperative X rays showed improved fit and positioning of the femoral components. Another prospective randomized controlled trial of the ROBODOC and conventional manual implantation was reported from Germany.[45] Eighteen percent of the robot-assisted procedures required conversion to manual implantations. Two-year follow-up revealed no difference in Harris hip scores, however, the robot-assisted group had more dislocations and revisions.[40] The authors concluded further development of this technology was needed before widespread usage can be justified.

The active constraint robot (ACROBOT) is an orthopedic robot designed specifically for knee replacement surgery. The ACROBOT's end-effector has six degrees of freedom with a rotary cutter and detachable cutter motor. The surgeon guides the robot while the robot provides geometric accuracy and motion constraint to improve safety. Preliminary results on a limited number of patients have been encouraging.[46] More recently, a prospective randomized controlled trial of 34 total knee replacement surgeries was published. Accuracy was improved with the ACROBOT system, with all of the patients in the ACROBOT group having tibiofemoral alignment within 2° of the planned position, versus only 40% in the conventional group. Short-term follow-up demonstrated similar outcomes. Long-term results are needed before this technology finds widespread acceptance.

3.5. Conclusion

Most robot-assisted surgeries have proven to be safe and effective, however, longer operative times and unknown long-term morbidity and outcomes are current limitations. The reported longer operative times may be due to inexperience and will likely continue to improve as more surgeons gain familiarity with robot-assisted surgical techniques. There are many ongoing trials attempting to answer these questions, so data demonstrating outcomes and the cost effectiveness of these techniques will be forthcoming in the next decade. Lastly, as more advanced robots are developed, and additional technology is applied, such as image-guided surgery, traditional operating techniques may become antiquated.

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4

An Overview of Adult Robotic Urologic Surgery

Fatih Atug and Raju Thomas

4.1. Introduction

Rapid technological developments in the past decades have produced new inventions, such as robots, and incorporated them into our life. Today, robots perform vital functions in homes, outer space, hospitals, and military installations. Surgical robots have come to the forefront of the market in the past few years, and have started to occupy both space and time in operating rooms in numerous medical centers in United States and overseas. In addition, new robotic urologic surgical applications and techniques are being developed and reported everyday. This chapter briefly reviews the use of robotics in surgery, focusing on its specific applications in urology.

4.2. General Applications of Robotics in Adult Urologic Surgery

Urology is undergoing an immense technological revolution with the introduction and application of robotics in urologic surgery. Robotic-assisted surgical techniques are proliferating rapidly across the world. Usage of a surgical workstation that controls the robotic movements within the patient has truly brought laparoscopic surgery a quantum leap over traditional laparoscopic techniques, with its precision in cutting and more importantly, reconstruction and suturing. Cases that had been managed previously with conventional laparoscopy can be done elegantly and with greater ease with the da Vinci® robot. The most commonly performed robotic urologic procedures are briefly outlined below.

4.2.1. Robotic-Assisted Laparoscopic Prostatectomy

Robotic-assisted laparoscopic prostatectomy (RALP) is the most commonly performed robotic operation in the world. None of the robotic operations has been established as well as RALP. It has been estimated that 2648 RALP procedures were performed in 2003 and 9000 RALP in 2004. The number for 2005 will be approximately 16,500 cases, or nearly 20% of all radical prostatectomies performed for the year.

Radical prostatectomy is a technically challenging procedure that requires precise dissection and suturing skills. It has been estimated that a seasoned laparoscopic surgeon takes at least 40 to 80 cases to overcome the learning curve associated with laparoscopic radical prostatectomy. In contrast, the three-dimensional (3D) imaging capability and articulating instruments afforded by modern robotic systems appear to have shortened the learning curve.[1–4] Reports suggest that there are significant reductions in estimated blood loss, transfusion rate, length of stay, catheterization time, and perioperative complications with RALP once the learning curve is overcome.[1–7]

Although the early results are encouraging and suggest that immediate results are comparable to radical retropubic prostatectomy, long-term outcomes of erectile function, continence, and disease recurrence are still pending. It is likely that outcomes analysis in these areas will become the measuring stick with which the robotic approach will be measured. Urologic surgeons need to be cognizant of the paucity of prospective randomized data in the literature. Nevertheless, the early results are encouraging and further comparisons are eagerly anticipated.

4.2.2. Robotic-Assisted Pyeloplasty

Robotic surgery is also being successfully applied to reconstructive procedures, such as pyeloplasty. The main advantage of robotics over standard laparoscopy is facilitation of intracorporeal suturing and reconstruction (Figure 4.1). The first robotic-assisted pyeloplasty (RAP) was performed by Sung and co-authors in 1999 in a porcine model.[8] They performed a pyeloplasty with the Zeus® robotic system (Computer Motion, Santa Barbara, CA) and concluded that RAP is a feasible and effective procedure that may enhance surgical dexterity and precision.

Following this first clinical experience, RAP provided satisfactory results in a limited number of patients.[9–11] Gettman and colleagues compared laparoscopic pyeloplasty performed with the daVinci® robotic system (Intuitive Surgical Inc., Sunnyvale, CA) versus traditional laparoscopic techniques. He reported shorter overall operative and anastomotic times with the robotic approach.[12] Moreover, Yohannes and colleagues have demonstrated that the learning curve associated with intracorporeal suturing is shorter with the daVinci® robotic system than with conventional laparoscopy.[13] Thus, according to reported studies, RAP can be performed safely with results comparable to open pyeloplasty.[9–11,14]

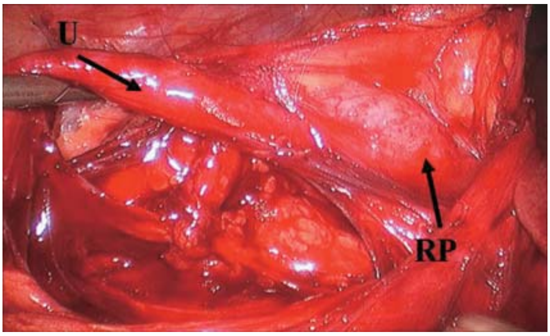

FIGURE 4.1. Intraoperative picture of robotic pyeloplasty operation. Dissection of ureter and renal pelvis. Abbreviations: RP, renal pelvis; U, ureter; CV, crossing vessel.

In addition, high success rates are reported with RAP. Siddiq and colleagues reported their experience in 26 patients with RAP. The overall clinical success rate was 95%, with a median follow-up of six months.[15] In another study, Palese and coworkers reported 94% success in 35 patients with a mean follow-up of 7.9 months.[16] Recently, Patel reported unobstructed drainage in 48 of 50 patients with a mean follow-up of 11.7 months.[17]

The technically demanding aspect of intracorporeal laparoscopic suturing is minimized with the robotic interface. RAP may prove to be one of the applications that demonstrate a clear advantage of robotics being applied to a minimally invasive approach. The outcomes of RAP can be easily compared to the open and laparoscopic counterparts as objective studies can confirm success. The one obstacle to overcome in such analyses is to standardize follow-up studies.

4.2.3. Robotic-Assisted Radical Cystectomy

The first robotic-assisted radical cystectomy was reported in 2003 by Menon and colleagues.[18] They used the da Vinci® robot to perform cystoprostatectomy and bilateral pelvic lymph node dissection in 17 patients. Specimen retrieval and bowel reconstruction was performed extracorporeally through a small incision, while a neobladder was sutured to the urethra robotically. They concluded that the da Vinci® robotic system allows for precise and rapid removal of the bladder with minimal blood loss. Additionally, robotic-assisted radical cystectomy (RARC) with totally intracorporeal creation of an orthotopic neobladder has been reported.[19] Menon and colleagues recently reported RARC and urinary diversion in female patients. Moreover, they preserved the uterus and vagina in two patients.[20]

Today, reconstruction parts of RARC operations are performed mostly outside. Extracorporeal reconstruction of the urinary tract reduces operative time at this stage of evolution of laparoscopic and robotic instrumentation. In the future, with further advancement of technology, instrumentation, and with additional refinement of our technique, the entire procedure may be done completely intracorporeal with equal efficiency.

Consequently, with increasing skill and experience, urologists are likely to use robotics more extensively for different types of urinary diversions and reconstructions. This is not a commonly performed procedure and oncologic outcomes and efficacy are still pending.

4.2.4. Robotic-Assisted Vasovasostomy

Robotic-assisted vasovasostomy (RAVV) may be a sound option to conventional microscopic vasovasostomy. There are several reasons for this judgment. The 10x magnification, stable platform, and motion scaling properties of robots removes the physiologic tremor and makes suture placement easier and more precise. On the other hand, the learning curve for RAVV is shorter than conventional microscopic vasovasostomy. In 2004, Schiff and colleagues reported a randomized prospective study of vasoepididymostomy and vasovasostomy using the da Vinci® robot in rats.[21] They reported that the improved stability and motion reduction during microsurgical suturing provided by the robotic system reduced anastomotic time significantly in the RAVV (102.5 vs. 68.5 min, respectively). The patency rates were found to be 100% for the RAVV and 90% in the microsurgical vasovasostomy groups. Sperm granulomas were found in 70% of microsurgical vasovasostomy anastomoses and 27% of RAVV anastomosis.[21]

In a recent study, Kuang and colleagues assessed the feasibility of a multilayered RAVV in a rabbit model. They demonstrated that a multilayered RAVV could be successfully performed.[22]

As surgical robots become increasingly used for a variety of procedures, the feasibility of RAVV will become more reasonable. Although robotic surgery has developed and improved prostate surgery, its contribution to microsurgical technique has the potential for a more profound impact.

4.2.5. Robotic-Assisted Sacrocolpopexy

The first robotic sacrocolpopexy was reported in 2004 by Di Marco and colleagues.[23] They reported that robotic-assisted laparoscopic sacrocolpopexy provided the same long-term durability of open sacrocolpopexy with the benefit of a minimally invasive approach.[23] Henceforth, the same results are reported by Elliot and colleagues. They reported that robotic-assisted sacrocolpopexy is associated with decreased hospital stay, low complication and conversion rates, and high rates of patient satisfaction.[24]

4.2.6. Robotic-Assisted Nephrectomy

The first robotic-assisted laparoscopic nephrectomy was performed in 2001 by Guillonneau and coworkers as a case report in a 77-year-old woman.[25] They reported that the procedure was technically feasible in humans. Later, Horgan and colleagues reported their experience with robotic donor nephrectomy in 12 patients.[26] Recently, robotic-assisted bilateral laparoscopic heminephroureterectomy has been reported by Pedraza and colleagues.[27]

However, being mainly an extirpative procedure, the marked advantages of robotics, such as intracorporeal suturing and reconstruction, are not needed in nephrectomy procedures.

4.2.7. Other Applications

Partial nephrectomy,[28,29] robotic adrenalectomy,[30] robotic-assisted kidney transplantation,[31] vesicovaginal fistula repair,[32] robotic-assisted laparoscopic ureteral reimplantation,[33] and robotic detrusor myotomy[34] are other urologic applications of robotic surgery today.

4.3. Conclusion

The availability of robots has been a tremendous boom to the delivery of minimally invasive urologic cases. Urologists who are not well versed in advanced laparoscopy can deliver precision-driven surgical procedures in a wide array of ablative and, especially, reconstructive procedures.

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5

Essential Elements of Building a Robotics Program

Garrett S. Matsunaga, Anthony J. Costello, Douglas W. Skarecky,
and Thomas E. Ahlering

5.1. Introduction

The first successful report of a laparoscopic nephrectomy was in 1991,[1] and just one year later Schuessler, Kavoussi, and Clayman (largely the same group responsible for laparoscopic nephrectomy) reported the first laparoscopic radical prostatectomy (LRP).[2] The continued development of LRP moved across the Atlantic Ocean when, in 1999, two groups in Paris reported fairly large series.[3,4] These groups had persevered and conquered the difficult learning curve of paving the way for the rapid advancement of this technique. Interestingly, LRP remains more vigorous in Europe and only a small number of American centers have embraced this technique. The group at Henry Ford Hospital stalled in their quest to establish a pure laparoscopic program and subsequently transformed into the first large-scale robotic-assisted laparoscopic radical prostatectomy (RLP) program using the da Vinci® robotics system (Intuitive Surgical Inc., Sunnyvale, CA).[5]

A limitation of robotics is the substantial financial investment. The surgical system costs $1.3 to $1.5 million dollars with an annual service contract of $100,000. In addition, there are other expenses to consider — operating room renovations, staff and surgeon training, and initial longer operative times. The costs of disposable and reusable instrumentation for LRP are considerably higher than for an open approach, however, reimbursement by insurance carriers remains unchanged. Indeed, one report of a cost analysis showed that cost equivalence between open versus LRP could not be reached even with decreased hospital stays, decreased operating room (OR) times, and case loads greater than 400 prostates per year.[6]

So how does one justify this investment?

Hospitals, surgeons, and patients may all benefit from a successful robotics program. Although there are no randomized controlled studies to demonstrate equivalence or superiority of LRP with open techniques, the short-term data is very promising. Oncologic outcomes as measured by surgical margins and postoperative continence and potency appear to be at least similar to open series. However, there is no question that visualization is superior to the open approach (12× magnification and decreased bleeding due to the pneumoperitoneum) and operative precision is optimized with the use of instruments with seven degrees of freedom. Patients also benefit from decreased pain, shorter convalescence, and improved cosmesis associated with minimally invasive laparoscopic techniques.

Some argue that a purely laparoscopic approach can achieve the same results as LRP. While this may be true for the most gifted of laparoscopic surgeons, there is a steep learning curve required simply to perform LRP, let alone master it and achieve superior outcomes. The robot has allowed nonlaparoscopically trained surgeons to transfer their existing open skills to a laparoscopic venue with a much less challenging learning curve.[7] Arguably, for practicing urologists who do not have the time to invest in mastering laparoscopic techniques, the robot offers the potential to expedite the transfer of their open skills to the laparoscopic arena.

There is no question, however, that patient interest in robotics is a powerful driving force. Patients are attracted to hospitals which they perceive as technologically advanced. Successful marketing by hospitals with robotics programs and the plethora of readily accessible information on the Internet have resulted in a well-informed patient population. In just five years, LRP has experienced exponential growth in the United States. In 2003, there were 2648 LRPs performed; in 2004, 7222 were performed; in 2005, over 16,000 were performed; and 25,000 cases are projected for 2006. LRP will approach 25% of the approximate 100,000 radical prostatectomies performed each year in the United States. Currently, there exists U.S. Food and Drug Adminstration (FDA) approval for urologic, cardiac, gynecological, and general surgery procedures (Table 5.1).

Hospitals are currently faced with two types of scenarios when deciding to launch a robotics program. They may be innovators looking to institute the first robotics program in their service area or they may be trying to prevent the further loss of patients to nearby hospitals with an established robotics program. In either case, factors such as service area, surgical volume, and the creation of a technically advanced hospital image must be considered. When looking at surgical volume, projections should include new out-of-service-area patient volume and cessation of loss of patients to other robotics programs.

The essential elements of establishing a robotics program are establishment of a robotic prostatectomy team, training of the robotic prostatectomy team, OR requirements, patient selection, outcomes measurement, financial issues, and marketing strategy.

Table 5.1. FDA-approved robotic-assisted procedures.

Urology	Radical prostatectomy, pyeloplasty, cystectomy, nephrectomy, adrenalectomy, ureteral reimplantation
General surgery	Cholecystectomy, Nissen fundoplication, Heller myotomy, gastric bypass, splenectomy, bowel resection
Gynecology	Hysterectomy, myomectomy
Cardiac surgery	Internal mammary artery mobilization and cardiac tissue ablation, mitral valve repair, endoscopic atrial septal defect closure, mammary to left anterior descending coronary artery anastomosis for cardiac revascularization with adjunctive mediastinotomy

5.2. Establishment of a Robotic Prostatectomy Team

The most important element in a successful robotics program is the *commitment* of its team members. This group of key individuals must navigate and persevere through formidable administrative, logistical, and operative challenges. There exist many institutions with robotic systems that lie fallow in prostatectomy for lack of dedicated champions.

The robotic radical prostatectomy team requires:

1. **Administration support.** Hospital administration must be dedicated to the success of the robotics program. They should coordinate the financial commitment of the hospital administration, surgeons of varying disciplines, and OR personnel. Hospital boards and chief executive officers (CEOs) must envision the integral role of robotics in current and future surgery and support its establishment.
2. **Dedicated console surgeon(s).** A dedicated console surgeon committed to mastering the robotic technique and improving patient outcomes is essential to the success of the program.
3. **Tableside assistant with laparoscopic skills.** At our institution this is a position occupied by a fellow in robotic surgery, who has a one-year post. The assistant surgeon plays an active role in the operation — suction, retraction, cutting and passing sutures, and removal of final specimen. The importance of having a tableside assistant with laparoscopic skills cannot be underestimated. Case times are prolonged when a new or laparoscopically naïve assistant is involved, regardless of console surgeon experience. A fourth arm is available at extra cost. The fourth arm enables the surgeon to retract and hold sutures independent of an assistant. *However, it should be emphasized that the fourth arm cannot take the place of a laparoscopically skilled assistant surgeon.*
4. **Operating room staff.** In our hospital, there were initially two registered nurses (RNs) and one scrub technician that were trained in robot

setup, tableside assisting, and circulating. Maintaining the same three staff members for every robotic case for the first six months was critical in creating consistency between cases. This staff consistency improved efficiency during and between cases and also contributed to a sense of esprit de corp. Our dedicated staff would stay late to finish cases, which eliminated staff changes mid-case. In turn, our staff was invited to attend educational meetings as well as various social events (100th case, resident graduation, etc.).

5. **Anesthesia team.** The robotics program must prevail over the technical challenges to anesthesia. Initial prostatectomy cases may run between six and eight hours for patients in the steep Trendelenburg position. This position restricts lung expansion resulting in higher peak ventilatory pressures. Combined with elevated pCO_2 from the pneumoperitoneum requires vigilance. Prolonged steep Tredelenburg can also lead to significant facial and corneal edema. We have experienced several corneal abrasions. Placing disposable protective eye goggles on the patient, which are left in place until full anesthetic recovery has been accomplished, has eliminated this complication.

5.3. Training of the Robotic Prostatectomy Team

It is mandatory for surgeons to avail themselves to the several levels of training dedicated to LRP. Introduction to robotic clinical practice is now widely available at multiple regional and national courses and symposia. Hospitals generally require completing an Intuitive Robot Training course for credentialing. All surgeons and supporting OR staff must complete this two-day basic robotics course. This course emphasizes the various parts of the robot, robot setup, and basic use of the console. The second day consists of animal practice for the surgeons. Various extirpative and reconstructive tasks are planned to familiarize the surgeons with the various robotic instruments as well as basic patientside assisting. For OR staff, the second day focuses on robot setup, draping, and proper maintenance.

Hospitals may require a minimum of proctored cases before a surgeon becomes credentialed to perform LRP. Nonlaparoscopic surgeons must master the principles of establishment of a pneumoperitoneum and concurrent CO_2 pressure hazards, etc. For the initial cases, it is advisable to have an Intuitive Surgical representative present in the operating room. In the event a surgeon or any other member of the robotic team has a question or problem, troubleshooting with a representative can occur immediately.

Robotics training has become an integral part of many fellowships and residency programs. At our institution, the endourologic fellows, robotic fellow, and senior residents are all involved with robotic surgery. A residency program in Rochester, NY, requires residents to complete initial da Vinci® certification training before training as a tableside assistant with an attending surgeon. Once tableside proficiency has been demonstrated, residents are then allowed to perform segments of the prostatectomy with the attending surgeons assisting and providing verbal instructions.[8]

5.4. Operating Room Requirements

Optimally, a dedicated room for the robot is desired. This allows minimal movement of the robot, which decreases setup time and decreases the chance of damage to the robot. The room should be of adequate size to accommodate the various components of the robot: console, patientside cart, two monitors, anesthesia, and scrub area/instruments.

At our institution, our usual room is 30 feet by 20 feet (Figure 5.1). While LRP have been performed in a smaller room (25′ × 15′), a larger room is desirable as it allows easy access for the circulating nurse and ancillary staff to work in the room. Other considerations include the integration of drop-down flat screen monitors, which eliminate the clutter of larger tower video systems.

As with all surgeries, optimization of the various steps of LRP is critical to ensure consistency between cases and to maximize efficiency, which decreases operative and turnover times. At our institution, the room setup remains constant as the single assistant is always on the patient's right and the scrub nurse is on the patient's left. All console surgeons use the same four robotic instruments and the bedside assistant stand is

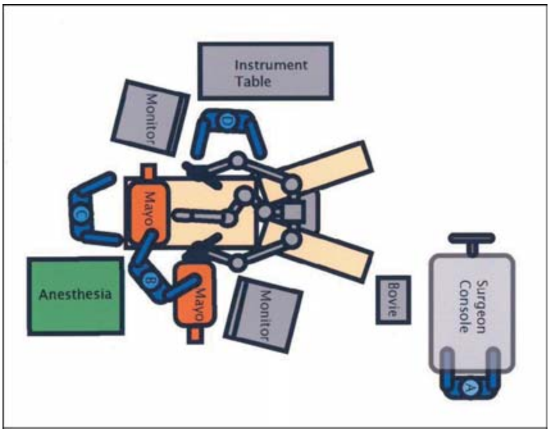

FIGURE 5.1. Operating room setup. (Reprinted from Lee DI, Eichel L, Skarecky D, Ahlering TE. Robotic laparoscopic radical prostatectomy with a single assistant. Urology 63:1172–1175, June 2004, with kind permission from Elsevier.)

setup with the same five instruments (Table 5.2). Individually packaged sterile robotic and laparoscopic instruments are immediately available if needed. Our circulating nurses also remain vigilant on the amount of CO_2 remaining in the tanks.

5.5. Patient Selection

5.5.1. Initial Learning Curve Guidelines

1. Patients should not be obese [body mass index (BMI) <30).
2. Prostate sizes by transrectal ultrasound should be less than 60 to 70 g.
3. Avoid men with prior history of previous abdominal surgery (e.g., hernia repair).
4. Avoid men with previous transurethral resection of the prostate (TURP), trans-uretheral needle ablation (TUNA), hormone therapy, and/or radiation therapy.
5. Avoid men with identified large median lobes, chronic prostatitis, or anticipated tissue scaring.
6. Avoid nerve sparing or lymph node dissections.

TABLE 5.2. Standard equipment for LRP.

- Robotic instruments
  - Monopolar scissors
  - Maryland bipolar forceps
  - Large needle driver (2)
  - (Prograsp for fourth arm)
- Assistant's Mayo stand
  - Laparoscopic atraumatic bowel grasper
  - Laparoscopic traumatic locking grasper
  - Laparoscopic scissors
  - 10-mm Endocatch^{TM} bag (US Surgical, Norwalk, CT)
  - Laparoscopic 45-mm EndoGIA^{TM} with vascular load (Ethicon Endosurgery, Cincinnati, OH)

Success of launching a robotics program is reliant on all members of its team. After each initial case, it may be helpful to have a group meeting with surgeons, anesthetists, and OR staff to review and critique performances. This should be a constructive forum for all to benefit and improve as opposed to assigning blame or highlighting shortcomings.

For the first 10 cases, it is advisable to have an Intuitive Surgical representative present in the OR. In the event a surgeon or any other member of the robotic team has a question or problem, troubleshooting with a representative can occur immediately. Once the team gains more experience, the representative or engineer's emergency contact information can be posted somewhere in the room for quick access. Intuitive Surgical can also provide an experienced LRP surgeon to proctor for the first several cases. This proctor can be invaluable during the first several cases by giving instruction or surgical tricks.

5.5.2. Post Learning Curve

Although the learning curve for four-hour surgical times may be accomplished in as few as 15 men (Figure 5.2), learning still persists on technical steps (e.g., bladder neck dissection, anastomosis, etc.) beyond these initial cases. After the initial learning curve, the patient profile may be extended to obese patients, larger prostates, previous abdominal surgeries, retroperitoneal pelvic lymph node dissection (RPLND), clinical T3 cancers, poor Gleason grades (8–10), or salvage prostatectomy. Prior mesh hernia repair and/or the presence of inguinal hernia are not contraindications. Endoscopic repair of inguinal hernia is very simple and the insertion of mesh in the inguinal canal takes less than five minutes. It is easy to repair inguinal and umbilical hernias even in the learning curve.

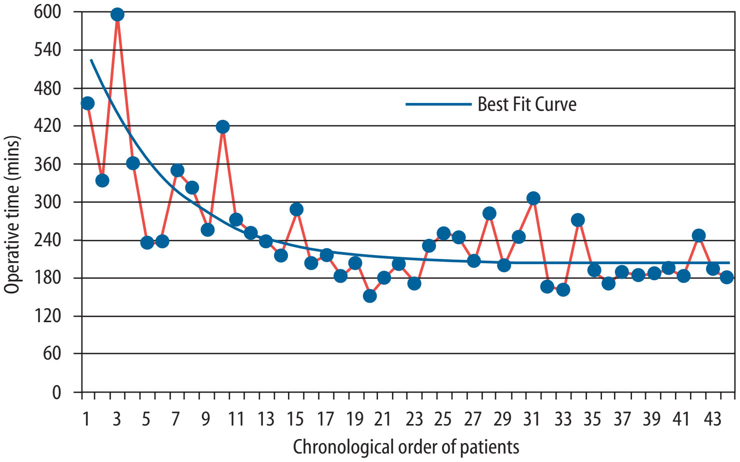

FIGURE 5.2. Laparoscopic radical prostatectomy learning curve: University of California, Irvine, Experience. (Figure reprinted from Surgical Endoscopy 2004;18:1694–1711, with kind permission of Springer Science and Business Media.)

5.6. Outcomes Measurement

The considerable commitment to the robotic program must be proven by increased patient benefit. The only way to identify areas of potential improvement is to continually monitor outcomes. Preoperative, operative, and postoperative data collection (Table 5.3) is obtained from every patient undergoing LRP at our institution. Although data collection can be arduous and time consuming, judicious streamlining of questionnaires can give increased patient compliance and a quick "snapshot" into their improvement at various stages of postoperative follow-up. Patients can be given one-page questionnaires to track continence, pad usage, American Urological Association (AUA)/bother urinary symptom scores, and short Sexual Health Inventory for Men 5 (SHIM-5) potency scores. Initial pre- and peri-operative patient information can be quickly entered by the primary surgeon into a spreadsheet database. An administrative specialist can facilitate postoperative data collection and database updating. Additionally, patient follow-up will become more accessible with e-mail or Internet-based data collection systems.

TABLE 5.3. Suggested data collection.

- Preoperative
  - Patient information
  - Number of positive biopsy cores and location(s)
  - Clinical stage
  - Gleason grade
  - Prostate-specific antigen (PSA) level
  - Prostate size by transrectal ultrasound (TRUS)
  - International Prostate Symptom Score (IPSS)
  - Sexual Health Inventory for Men (SHIM)
- Operative
  - OR time
  - Estimated blood loss
  - Hospital stay
  - Complications
- Postoperative
  - Positive surgical margin and location
  - Pathologic Gleason score
  - Pathologic prostate weight
  - PSA/recurrence
  - SHIM score
  - IPSS score
  - Expanded Prostate Cancer Index Composition (EPIC) — urinary function

5.7. Financial Considerations

Financial planning for a robotics program will vary between regions. Creative lease agreements or identification of a philanthropist who may wish donate a robot can facilitate initial acquisition of the robotics program. Other considerations include the cost of addition staff and their training, disposable robotic instrumentation, marketing, service contract ($100,000/year), data collection and analysis, and continuing medical education.

5.8. Marketing Strategy

Promotion of a newly created robotics program is advisable. Centers have employed all forms of publicity, such as local newspapers and magazines, either via profiling articles or standard advertising. Radio and television advertising are more expensive options, but can be very effective. Hospital and surgeon websites should have information about the robotic services provided with appropriate links.

5.9. Conclusion

Establishment of a robotics program requires the commitment from hospital administration, surgeons, and OR staff involved. Effective planning prior to acquisition of a robot can be the difference between the success or stagnation of a program. Perseverance, good communication, and continuing education facilitate ongoing success of a program that can bring prestige and subsequent pride to members of the robotics team and all affiliated with its hospital.

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6

Principles and Lessons in a Transition from Open to Robotic-Assisted Laparoscopic Prostatectomy

Joseph A. Smith, Jr.

Debates about a preferred surgical approach are not new for radical prostatectomy nor limited to this surgical procedure. The relative merits of retropubic versus perineal radical prostatectomy have been considered and discussed for over 50 years and each approach still has its proponents. Pure laparoscopic and robotic-assisted laparoscopic prostatectomy (RALP) are now not only feasible but widely practiced, further expanding the options and debate.

Often, a surgeon's preference is established during residency training wherein skills with a certain technique or approach are acquired. Sometimes more problematic, though, is when an experienced clinician wants to adapt a new surgical approach to his practice. Abandoning one technique with which a surgeon feels quite comfortable for another wherein he is a novice creates issues regarding training, patient safety, and efficiency. This is the dilemma faced by many urologic surgeons experienced with open radical prostatectomy who are contemplating the introduction of laparoscopic prostatectomy into their practice. While robotic assistance facilitates acquisition of some of the requisite skills, the initial learning curve is still daunting. Nonetheless, the basic surgical principles and anatomy are no different. Skills acquired with open radical prostatectomy are transferrable to laparoscopic approaches. In fact, the ideal surgeon performing laparoscopic prostatectomy, with or without robotic assistance, may be one who has complementary skills with open approaches.

This chapter outlines some of the observations acquired in transitioning from open radical prostatectomy to RALP. Further, comparative outcome measures are assessed. In addition, issues regarding the impact of RALP on clinical practice as well as residency training are discussed.

6.1. Technical Differences in Surgical Technique

Other than the obvious differences in access to the pelvis and periprostatic tissue, there are also differences in the sequencing and performance of some of the surgical steps for radical prostatectomy between a laparoscopic and retropubic approach. With RALP, either an intra- or extraperitoneal approach may be used.[1] Extraperitneal exposure creates a familiar working environment and allows separation of the intra- and extraperitoneal spaces for containment of any urine leak or, perhaps, tamponade of bleeding.[2] The disadvantage to an extraperitoneal approach is a smaller working space and more rapid loss of the pneumatic distension with any suction. Either way, though, the initial view of the prostate is one familiar to open surgeons.

The first step with either an open or laparoscopic approach is exposure of the prostate by developing the space of Retzius and displacing the fat overlying the endopelvic fascia and anterior prostate. The superficial dorsal vein becomes evident and can be directly cauterized. An incision is made in the endopelvic fascia just lateral to the prostate. An incision too far medial can open some of the large periprostatic veins and cause problematic bleeding. Again, this aspect of the procedure is virtually identical regardless of the surgical approach.

At this juncture, the order of the anatomic dissection usually becomes different between the two approaches. Most surgeons performing radical retropubic prostatectomy initially dissect the prostatic apex and divide the urethra. The prostate is then lifted from the rectal surface and dissected from the bladder neck in a retrograde fashion. With RALP, the dissection proceeds antegrade with division of the bladder neck first.[3] This is necessitated partly because of difficulty in visualizing the posterior prostate when the apex is divided first, as the camera angle is quite steep coming from the umbilicus. Further, the antegrade dissection potentially places less traction on the neurovascular bundle.

Because of this different approach, it initially may seem unfamiliar to open surgeons. With retropubic prostatectomy, the bladder neck is readily visualized by palpation as well as with the visualization which comes from complete dissection of the prostate prior to division of the bladder neck. With RALP, the bladder neck may be less evident and tactile feedback cannot be utilized. However, we typically have been able to perform a precise anatomic dissection of the bladder neck by relying upon observation of the visual contour of the prostate. The fat at the lateral bladder neck margin can be divided and this helps expose the prostatovesical junction.[4] Once the anterior bladder neck is divided, a median lobe can be easily identified and lifted anteriorly to allow posterior bladder neck dissection.

With a retropubic prostatectomy, dissection of the seminal vesicles usually introduces little risk of rectal injury. With an antegrade RALP dissection, establishing the proper plane of dissection posterior to the seminal vesicles becomes key both in avoiding rectal injury and helping identify the lateral pedicle and neurovascular bundle. Because of the potential difficulties in this maneuver, some surgeons continue to use the Montsouris approach wherein the seminal vesicles and rectal plane are approached through the pouch of Douglas.[5] Once familiarity with the visual landmarks is achieved, we have had no difficulty identifying the proper planes by simply dissecting directly over the seminal vesicles after dividing the posterior bladder neck. Upward traction on the seminal vesicles once mobilization is complete identifies the posterior layer of Denonvilliers fascia. This layer can not be opened safely by blunt dissection. This view of Denonvilliers fascia may be unfamiliar to surgeons experienced only with radical retropubic prostatectomy. However, complete sharp incision of the posterior layer of Denonvilliers fascia allows identification of the perirectal fat and direct entry into the proper plane. Continued mobilization of the rectum from the posterior surface of the prostate all the way to the level of the urethra is desirable and facilitates subsequent portions of the procedure.

The next step in the operation is control of the vascular pedicle. At this point, the pedicle should be readily visible. As with open surgery, various methods have been described to control the pedicle but we have found placement of locking Weck clips to be preferred (Figure 6.1). These are easily placed, offer excellent hemostasis, and avoid use of any thermal energy.[6] Once the pedicles have been controlled, the neurovascular bundle must be dissected from the prostate. The superb visualization with RALP permits precise dissection of the neurovascular bundle. A key surgical judgment, regardless of approach, is how aggressively the surgeon should pursue hemostasis in dissecting the neurovascular bundle. Excessive bleeding not only obscures vision during the

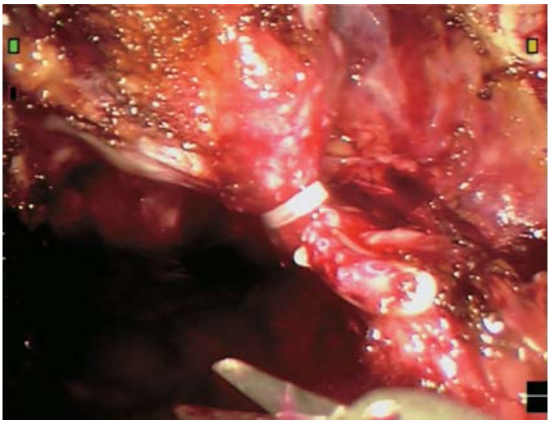

Figure 6.1. Division of the anterior bladder neck during RALP. Despite the loss of tactile feedback, good anatomic definition of the vesicoprostatic junction can be obtained by exposing the contour of the prostate.

procedure but introduces a risk of postoperative hematoma. On the other hand, too vigorous of an effort to gain hemostasis can damage the nerves. The tamponade effect of the pneumoperitoneum is undoubtedly helpful but it does not take much bleeding to obscure the magnified operative field with RALP. The judgment of how much hemostasis is necessary and when it is too much relies upon surgeon experience, irrespective of surgical approach.[7]

Likewise, principles of the apical dissection are similar regardless of an open versus a laparoscopic approach. Good hemostasis from the dorsal vein complex is necessary for adequate visualization of the prostatic apex because that is the most common site of positive margins. Concerns about maximizing urethral length to avoid incontinence should not lead to inadequate excision of the prostatic apical tissue. There can be a lip of posterior prostatic tissue that can be violated after incision of the urethra if the surgeon is not sufficiently diligent.

Typically, with a radical retropubic prostatectomy, interrupted sutures are used for the vesicourethral anastomosis. RALP permits a running anastomosis that often is extremely precise and immediately watertight.[8] With both approaches, mucosal-to-mucosal approximation is the goal and incorporation of excessive amounts of urethra in the sutures should be avoided. A drain can be removed on the first postoperative day if the output is minimal and we have seen nothing to gain by avoiding drain placement regardless of the surgeon's perception of the quality of the anastomosis.

6.2. Patient Selection

Most patients with apparently localized carcinoma of the prostate are good candidates for either open or robotic-assisted laparoscopic prostatectomy. Ideally, the tumor is confined within the prostatic capsule and amenable to complete removal with surgery. However, there are criteria that make one surgical approach preferable over the other in some patients.

Typically, factors which make the operation more difficult with open surgery also apply to RALP. Obesity can limit access to the prostate via either a retropubic or laparoscopic approach. A patient who is so obese that the laparoscopic instruments cannot reach the pelvis is probably not a good candidate for radical prostatectomy in the first place. A previous transurethral prostatectomy can create some periprostatic scarring and thinning of the anterior prostate. Also, the bladder neck may be much larger after a prior transurethral resection of the prostate (TURP). Again, this can be managed via either surgical approach.

A large median lobe does not preclude RALP. The median lobe can be identified, grasped, and lifted anteriorly to expose the trigone and posterior bladder neck. As with open surgery, excision through the posterior bladder neck may be relatively close to the ureteral orifices and identification of the orifices may be facilitated by administration of indigo carmine dye.

Prostate size is a consideration. Identification of the prostatic apex is sometimes difficult through an open approach when the prostate gland is quite small. This has seemingly been less problematic with RALP. A very large prostate in excess of 100 cc can make the operation more difficult with either approach but we have performed RALP successfully with prostate volumes over 150 cc. Tumor volume probably does not influence selection of surgical approach. With either RALP or radical retropubic prostatectomies (RRP), the plane of dissection can be immediately adjacent to the prostate or it can widely encompass the neurovascular bundle.

A history of prior abdominal surgery can be influential in deciding upon which approach to use for radical prostatectomy. Commonly, patients have undergone inguinal hernia repair, often with mesh. Especially when a bilateral repair is performed, the mesh may cross the midline and obscure the retropubic space. This typically is less problematic with RALP. Although the bladder may be densely adherent to the mesh, it can be safely dissected away from the undersurface of the mesh and, with RALP, it is unnecessary to divide mesh after inguinal hernia repair. A prior umbilical hernia repair can create difficulties with periumbilical laparoscopic access. Usually, though, development of a space for placement of the camera port can be performed safely. A history of appendectomy rarely is a contraindication to RALP. Right lower quadrant scarring is sufficiently removed from the operative field but, sometimes, takedown of adhesions is required.

A prior laparotomy, especially with an incision that extends well below the umbilicus, can create problems with intraperitoneal access for RALP. This is particularly true when there is a history of sigmoid colon resection and anastomosis as the scarring between the dome of the bladder and the intraperitoneal contents may be severe. Extraperitoneal RALP can be considered in this circumstance but the anterior abdominal wall scarring can still limit some of the insufflation.

When a patient who desires RALP has had prior surgery that may limit access, we will sometimes plan an attempt to gain appropriate exposure with the caveat that we will move ahead with an open procedure if problems are encountered. Experienced surgeons realize that scarring from prior surgery is difficult to predict and may be much greater or less than anticipated. A well-trained surgeon with experience with multiple approaches has flexibility that can facilitate overall patient management.

6.3. Comparative Results

As discussed above, most surgeons settle on a particular approach because of familiarity gained during residency training. In order for a practitioner to adopt a new technique, there must be some perceived advantages. Marketing and patient expectations have partially driven some of the interest in RALP. However, most intra-institutional comparisons have shown decided advantages for RALP compared to RRP. These series are sometimes challenged by open surgeons who contend that RALP results are not superior to those achieved with RRP in the hands of an experienced surgeon.[9]

The results discussed below reflect the experience at Vanderbilt Hospital with a single surgeon who has performed over 2500 radical retropubic prostatectomies and almost 1000 robotic-assisted laparoscopic prostatectomies. Importantly, we have used the same postoperative care pathway regardless of whether a patient undergoes RALP or RRP. This lessens the difference in perioperative outcome between the two techniques. It is obvious, but important, to point out that a postoperative care plan that targets day 1 for discharge after RALP and day 2 or 3 for RRP will show a significant difference in length of stay. However, if the pathway is identical, as in our series, differences are more likely to be from true variances in the rate of recovery rather than simple differences in the treatment plan or strategy.

6.3.1. Postoperative Pain

It has been assumed that minimally invasive surgical approaches such as RALP are associated with less postoperative pain than open operations. For many surgical procedures, such as radical nephrectomy, this often is true. However, RRP can be performed through a limited, lower abdominal midline incision that does not usually cause substantial postoperative pain. We have been unable to demonstrate any difference in patient-reported pain or in narcotic use after either RRP or RALP.[10] The failure to demonstrate a difference is attributable to the low pain scores in both treatment groups despite no use of epidural catheters or patient-controlled analgesia.

6.3.2. Length of Stay

Our pathway targets postoperative day 1 for discharge regardless of whether an open or laparoscopic prostatectomy is performed. Over 90% of patients in both groups meet this target. Postoperative ileus is the most common reason that longer hospitalization is required. We have observed no difference in the duration of ileus between the two treatment groups.

6.3.3. Intraoperative Bleeding

Even in experienced hands, there is the potential for significant bleeding with RRP. The tamponade effect of the pneumoperitoneum and the division of the urethra as the final surgical step with RALP both contribute to the excellent hemostasis associated with this procedure. Minimal bleeding has been a consistent finding in virtually all reports of RALP.

In our prospective study, the median discharge hematocrit was statistically significantly better in

RALP patients (38%) compared to RRP (33%).[7] Autologous blood donation was not used in either group and homologous transfusion was required in fewer than 1% of the RALP patients and in fewer than 3% of patients after RRP. These findings underscore the following points: Significant bleeding requiring transfusion occurs in only a small percentage of patients undergoing RRP in our series. Nonetheless, our series also confirms the minimal blood loss and improved hemostasis with RALP compared to RRP.

6.3.4. Return to Activity

It is again commonly assumed and widely promoted that patients return to their presurgical activity levels more quickly after RALP. Whether this is true depends partly upon the postoperative instructions given. Even though the surgical incisions are relatively small, there is a risk of hernia, especially at the umbilical port site where the specimen is extracted. Therefore, we instruct patients to refrain from strenuous activity for one month to six weeks after RALP as well as after RRP. Our data collection on quality of life is incomplete but there are no studies that yet objectively document a better sense of well being or more rapid return to activity levels after RALP compared to RRP.

6.3.5. Continence

For many men, incontinence is the dominant concern when considering radical prostatectomy. Undoubtedly, significant incontinence has a substantial adverse effect on quality of life. Despite the frequency with which this operation has been performed over the years, the underlying anatomic and physiologic reasons for incontinence after radical prostatectomy are poorly understood. Nonetheless, it is recognized that careful dissection of the prostatic apex is key in avoiding incontinence. Further, a precise anastomosis can help limit scarring and inflammation, which may also be important.

The details of the apical dissection are identical for both open and robotic-assisted prostatectomy. Decisions about whether or not to divide the puboprostatic ligaments, whether to use a suture or stapling technique, and how much to incorporate anterior fixation of the periurethral tissue are made independent of surgical approach. However, at least in theory, RALP could provide advantages. Because of the excellent hemostasis, limited suturing of the dorsal vein complex is required (Figure 6.2). The periurethral striated sphincter muscle is easily visible and precise dissection can be performed. Also, the running, watertight anastomosis with RALP could offer advantages (Figure 6.3).

Most men ultimately regain good urinary control after radical prostatectomy so, in the end, differences are difficult to demonstrate.[11] Our

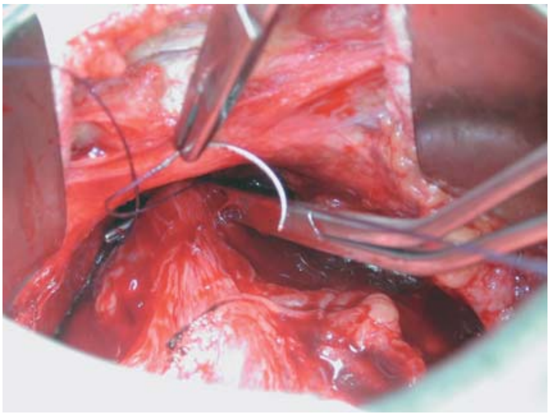

FIGURE 6.2. The right vas deferens has been divided and the ends are grasped with the left arms. The right seminal vesicle is readily identified.

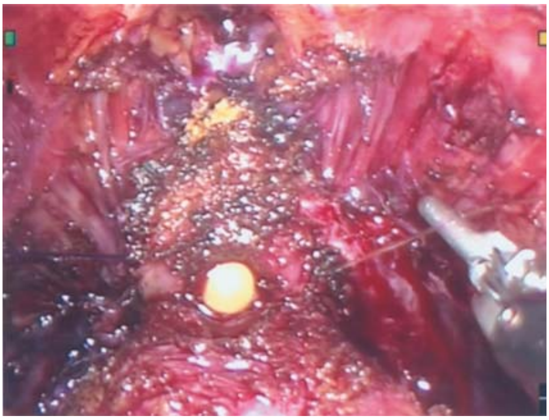

FIGURE 6.3. The posterior layer of Denonvilliers fascia has been incised sharply, exposing the perirectal fat.

data have not convincingly shown either a more rapid rate of return or continence after RALP nor better results ultimately at one year. These results show that a technically sound prostatic apical dissection can be accomplished with either approach. It is disturbing that a small proportion of men continue to have incontinence in both of our treatment groups and in virtually every reported series. Better knowledge and understanding of the reasons for this could help delineate technical maneuvers that may completely eliminate incontinence.

6.3.6. Erectile Dysfunction

Preservation of erectile function is undoubtedly related to technical aspects of radical prostatectomy. There is a fine line between a dissection that violates the prostatic capsule and one that preserves the structures of the neurovascular bundle. RALP offers superb visualization of the periprostatic fascia and neurovascular bundle. Further, the antegrade dissection may help limit traction injury to the bundle during the apical dissection. The promise of improved erectile function is one of the driving forces behind the adoption and promotion of RALP.

Again, comparative inter- and intrainstitutional studies have shown good results for RALP and, often, results superior to those with open surgery. Whether RALP routinely offers results superior to those achieved by highly experienced and skilled open surgeons remains a matter of debate.[12] It has been suggested, though, that surgeons with relatively modest or even moderate case volume for radical prostatectomy may be able to more routinely achieve good results with erectile function with RALP compared to RRP.

6.3.7. Margin Status

The goal of radical prostatectomy is complete removal of all prostatic tissue. Preserving continence and erectile function at the expense of leaving cancer cells behind does not benefit patients. However, every maneuver designed to avoid the side effects of radical prostatectomy places the dissection closer to the prostate and risks leaving positive margins. Virtually all studies have shown a gradual decline in the positive margin rate as the surgeon gains experience with RALP.[13] The high initial positive margin rate often is criticized by open surgeons. However, there are virtually no comparable studies detailing the positive margin rate as a surgeon goes from no experience with RRP to achieved expertise. Typically, the initial experience with RRP is during residency and in a supervised manner. Nonetheless, the potential for an increased positive margin rate early in a surgeons transition to RALP is a serious consideration for patients undergoing the procedure.

With experience, most studies have shown a positive margin rate with RALP that may be lower than with RRP. Our own experience mirrors that result. Currently, we are able to achieve a lower positive margin rate in pathologic T2 cancers with RALP than with RRP.

6.3.8. Training Issues

For a surgeon who did not learn RALP or, perhaps, even advanced laparoscopy during residency, adoption of RALP into an established clinical practice can be problematic. Training courses are available and useful but, as with any operation, true learning occurs by actually performing the operation.[14] The learning curve for RALP often is measured by the duration of surgery. While operative times decrease as experience is gained, the duration of surgery probably impacts little on patient morbidity as long as operative times are less than four to five hours. Most studies have shown that within 25 to 50 patients, operative times with RALP diminish substantially although the surgical duration depends not only upon the experience of the surgeon but also the entire operative team.

There basically are two aspects of RALP that must be mastered by an open surgeon making the transition. One is the simple mechanics of the robotic equipment. Dry laboratory practice can be very useful in acquiring the necessary suturing skills, movement of the robotic arms, and general familiarity with the mechanics of the robotic system. Although the pelvic anatomy and the basic principles of the operation are identical to open surgery, some of the surgical steps as mentioned above are somewhat different either in the sequence with which they are performed or in the approach. Multiple sources are available for viewing of recorded surgical procedures. Surgeons learning RALP should take advantage of opportunities to observe live surgical procedures.

6.4. Conclusion

Robotic-assisted laparoscopic prostatectomy is rapidly becoming both widely available and routinely used in many centers for treatment of apparently localized carcinoma of the prostate. Experience with the open operation facilitates acquisition of the skills necessary for the robotic procedure. Residents increasingly have the opportunity to acquire skills for robotic surgery during their training. Established practitioners who want to achieve expertise with robotic surgery must be willing to dedicate the time and effort necessary to learn the mechanics of the robotic system and the anatomic landmarks and dissection necessary for performance of the procedure.

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7

Training: Preparing the Robotics Team for Their First Case

Richard C. Sarle, Khurshid A. Guru, and James O. Peabody

Robotic prostatectomy is hard to learn but easy to do.

Good judgment comes from experience and experience comes from bad judgment. Many surgeons have heard this aphorism and understand its truth. It is self-evident that adequate training can and should take the place of the bad judgment that comes from inexperience. What constitutes an adequate training experience will depend on many factors and is likely to vary from institution to institution. In this chapter, we will discuss our philosophy of and experience with training in robotic surgery at the Vattikuti Urology Institute (VUI). This has developed and evolved over the almost 2400 robotic-assisted procedures, including radical prostatectomy, radical cystectomy, radical and partial nephrectomy, performed by our surgical teams.

Our robotic prostatectomy program began soon after the da Vinci® Surgical System (Intuitive Surgical Inc., Sunnyvale, CA) was approved by the U.S. Food and Drug Administration (FDA) in October 2001. It was one of the first to be developed and was quickly the highest volume program in the world. A brief description of the program's development and underlying philosophy may prove instructive.

Based on review of historical data from our institution, we felt that radical prostatectomy (RP) achieved a better result in terms of cancer control for most prostate cancer patients. We also felt that some patients chose nonsurgical treatments for their prostate cancer because of concern about potential morbidity associated with the surgery. We were impressed with the development of the laparoscopic radical prostatectomy (LRP) program of Guillonneau and Vallancien at the Institute Mutualiste Montsouris (IMM) in Paris[1] and its potential to achieve a less morbid, safer, and more successful outcome. Our institute had rudimentary laparoscopic skills at that time and we felt that in order to safely embark on a program of laparoscopic prostatectomy an intensive mentoring by experts like those at IMM would be necessary.

Led by Dr. Mani Menon, several staff members began intensive training in laparoscopic prostatectomy. This included several visits to IMM by our team to observe cases, as well as 12 one-week visits to the Henry Ford Health System by Vallancien and Guillonneau to proctor LRP cases. The initial cases were performed safely and effectively with the mentor's help.

After several visits by the IMM team, we leased the da Vinci® robot because we felt it might facilitate our performance of the LRP procedure. The initial experience with the robotic system confirmed this impression. We believed that the robotic system had specific application to LRP. Although our first several cases were challenging, with the help of our mentors during 20 to 30 cases, we were able to establish a technique of robotic-assisted laparoscopic prostatectomy known, at our institution, as the Vattikuti Institute Prostatectomy (VIP) procedure.[2]

We believe that the robotic system significantly reduces the difficult learning curve of LRP. That is not to say that the robotic system eliminates this curve by any means, but, because of the three-dimensional (3D) visualization and "wristed" instruments, it does dramatically decrease the difficulty of complex laparoscopic dissection and suturing. As such, while the LRP learning curve may be in excess of 50 cases, we believe that with proper planning, training, and mentoring, the robotic learning curve may be 20 to 30 cases in many situations.[3]

7.1. The Current Standard

Since the spring of 2001, we have performed over 2000 VIP procedures. Currently we perform the procedure in an average of 2.5 hours of total operative time, with 30% of cases being completed in less than two hours. Our patients are discharged on postoperative day 1 approximately 95% of the time, and our transfusion rate continues to be less than 2%. Recovery of continence and potency has been excellent and cancer control rates have improved over those we achieved with open radical prostatectomy.[4,5] Currently three staff members at the VUI routinely perform the robotic prostatectomy. Each of these surgeons has undergone an extended period of training that will be described below. In addition, residents and fellows at the VUI have extensive exposure to the robotic prostatectomy and are proficient at both assisting and performing all aspects of the procedure (Table 7.1).

7.2. The Decision to Start a Robotic Prostatectomy Program

Our institute performed 120 to 150 radical prostatectomy procedures per year when we began our robotics program in March 2001. An adequate surgical volume that allows for regular performance of the procedure will facilitate a program's ability to reduce its learning curve. Frequent repetition of the procedure will allow for the entire team to ingrain the fundamentals of robotic setup, anesthesia, patient positioning, port placement, and operative technique. The largest improvements in our operative time occurred when we performed cases on consecutive days. A program without significant volume that performs the procedure irregularly will progress along the learning curve more slowly because the team is more likely to forget certain aspects of the setup and procedure during periods of inactivity, and this may impact the eventual success of a program. While a specific number of cases is not easy to define, an institution performing less than a four or five prostatectomy cases per month may be challenged to develop a successful program. With this in mind, performance of cases several days in a row at the beginning of the program can help to inculcate the principles necessary in all the team members. Without significant volume, the time between cases only further delays the programs achievement of competence.

Table 7.1. The Vattikuti Urology Institute training program.

Work with nurses and assistants to learn robotic setup and function.
Review recordings of the procedures to gain knowledge of procedure.
Participate as second patientside assistant (left side) on 30 VIP cases.
Participate as primary patientside assistant (right side) on 30 VIP cases.
Graduated mentored experience on console from more basic to more complex portions of the procedure over 50 cases.
Mentored performance of entire procedures until mastery achieved over 50 cases.

7.3. The Robotic Team

We organized our team around a primary surgeon and two assistant surgeons. The team was augmented by an anesthesiologist and two operating room nurses. The primary surgeon was the console surgeon for the first 30 to 40 cases performed by the team, while the assistant surgeons were consistent through the initial 50 to 60 cases. During this time the team developed a consistent technique. The team members became familiar with the steps of the procedure by being present for all the cases and by reviewing the video recordings of the procedures as well as the pathologic results. This allowed for transition of additional team members to the console surgeon position. As the team worked together and became more familiar with the robotic system, dramatic reductions in time to system setup, port placement, and operative steps occurred and helped decrease the total operating room (OR) time.

While the robotic system can allow a nonlaparoscopic surgeon to perform complex laparoscopic maneuvers at the console, we feel that at least one of the assistants should have significant previous laparoscopic training and be comfortable with basic laparoscopic techniques, including establishment of pneumoperitoneum through various techniques, safe port placement, exposure and manipulation of tissues, suctioning passage of suture and retrieval of needles, bagging of specimens, and port closure. The fine points of these techniques are challenging and are not easily mastered by the novice laparoscopic surgeon. Assistants can benefit from mentoring and careful study of recorded cases to learn proper techniques. We feel that careful mentoring of the patientside assistants can greatly reduce the learning curve for the assistant and the team.

While the surgeons play a crucial role, an anesthesiologist familiar with laparoscopic anesthesia is critical to patient safety, especially in the early stages of the program when cases are likely to be of longer duration. The head down position used by many teams coupled with the intraperitoneal approach can create difficulties with high ventilatory pressures and carbon dioxide retention. Anesthetic techniques to deal with these problems should be familiar to the team.

Finally, the scrub and circulating nurses play important roles in facilitation of cases. A team that can efficiently prepare the robotic system, including the draping and calibration of lenses, will make possible earlier start times and more rapid case turnover. The nursing staff should rehearse with the rest of the surgical team so that all parties know what equipment is regularly needed and also have available instruments suture and catheters that are needed less frequently. The steps of the operation should be known so that each item will be available as it is needed. Initial cases are also often supported by Intuitive Surgical, and their representatives can provide important troubleshooting tips during the initial phases of a program (Table 7.2).

Table 7.2. Attributes of a successful robotic team.

Familiarity with basic laparoscopic techniques.
Excellent laparoscopic support.
Familiarity with steps of robotic prostatectomy.
Console surgeon experienced in open anatomic radical prostatectomy.
Familiarity with laparoscopically viewed anatomy.
Understanding of patient positioning.
Familiarity with port placement for robot and setup of robot.
Facility with changing and cleaning lenses, troubleshooting robot.
Initial cases mentored.
Review of case recordings and results.

7.4. Preparation Before the First Case

We recommend that the surgical team spends time reviewing both recorded and live case demonstrations prior to performance of the initial procedure. Familiarity with the steps of the procedure and their appearance in a laparoscopic view can help an "open" surgeon appreciate subtleties of the procedure more rapidly. Even surgeons with substantial open radical prostatectomy experience can find the anatomy of the pelvis in the laparoscopic view somewhat disorienting. Tissue planes are approached from a different direction and the lack of tactile feedback can initially make the dissections more challenging. Once familiar with the steps of the procedure and important anatomic landmarks, surgeons often develop an even greater appreciation of the view afforded to them of the deep pelvis by the robotic system and can perform the operations more precisely.

Surgeons and teams interested in starting a program are required to complete the Intuitive Surgical online course that teaches them about the various components of the robotic system and instrumentation. After completing online training, surgeons usually are exposed to the robotic system in the dry laboratory setting. This initial exposure to the robotic system is a crucial part of training because it allows the team to begin to learn how to manipulate the system. The more quickly a team becomes familiar with the setup and manipulation of the device the more rapidly they will proceed to successful completion of the procedures. The next step involves dry laboratory drills with manipulation of beads, rings, and wires, and performance of suturing and knot tying. The 3D vision and wristed instrumentation make these initial tasks much easier than would be the case with traditional laparoscopy. These techniques are still difficult in the beginning of one's experience and the mechanics can be practiced using a pelvic trainer. We have found that intracorporeal suturing techniques, such as understanding and ingraining the fundamentals such as direction of needle passage and learning to hold proper tension on the suture, are best refined at this stage. It is important for console surgeons to master these prior to embarking on live cases.

While the basics of these manipulations are accomplished, it is critical that the surgeon become familiar with the camera and instrument clutching mechanisms (the left lateral pedal on the console). These allow the surgeon to work in a comfortable, more ergonomic position. We have observed several novice robotic surgeons working with the camera system too far away or off center from the point of dissection, or with their hands on the masters in a nonoptimal position, compromising their ability to perform the procedure with maximum accuracy. In this way the clutching is very much like driving a car with a manual transmission. In the beginning much thought is put into meshing the clutch and gear manipulations and over time it becomes second nature.

After completing the dry laboratory experience, the team should proceed to an animal laboratory and perform various urologic procedures, including prostatectomy. This gives the console surgeon and assistant's hands-on experience with living tissues and the opportunity to manipulate these tissues for suturing and gaining hemostasis. The opportunity to work in an environment without haptic feedback is usually a new one, and it allows the surgeon to become accustomed to the visual cues that are important in assessing tissue characteristics and strength. Performance of several procedures on each animal is recommended to maximize the opportunity for tissue dissection and reconstruction.

Cadaver laboratory experience is also recommended by some and will be of particular use to those teams without substantial experience with laparoscopic prostatectomy, allowing increased familiarity with the surgical approach.

7.5. Patient Selection

Optimal patient selection can also help to reduce OR time and complication rates in a surgeon's initial experience (Table 7.3). We recommend beginning with patients who have a low cancer burden. Patients should have a prostate-specific antigen (PSA) level of less than 10 and a lower volume of Gleason grade 6 cancer. This will decrease the likelihood of positive surgical margins in the initial cases. In addition, to diminish the impact of suboptimal nerve sparing, patients with low Sexual Health Inventory for Men (SHIM) scores or those in whom preservation of sexual function is not important should be in the initial group of patients.

Table 7.3. Criteria for selection of ideal initial patients.

Prostate size: 30–40 g
BMI: 23–28
No previous prostatic or abdominal surgery
Erectile dysfunction
Low-risk disease: PSA < 10 ng/mL and Gleason score < 7
Minimal LUTS
Healthy: no chronic obstructive pulmonary disease (COPD)
No androgen ablation therapy

Patient height and weight are also important considerations in the initial phases of a program. While experienced teams can routinely perform cases on patients with a body mass index (BMI) of over 32, we recommend that initial patients have a BMI in the range 23 to 28. Thinner patients have more easily identified anatomic landmarks and less abdominal fat, making the task of newly trained assistants less difficult in regard to port placement and retraction.

Previous abdominal surgery should also be an important consideration. It is helpful to a program to begin with patients who have not had previous abdominal surgery or inflammatory conditions in the bowel. This will decrease the possibility of bowel adhesions that increase the operative time and the risk of bowel injury during their takedown. While a mature program can eventually attempt the procedure on a patient with extensive previous abdominal surgery, we advise an unoperated abdomen in the initial cases. We believe that most bowel injuries occur during the takedown of these adhesions prior to docking the robotic system. Previous prostatic surgery with resection and thermal therapy with a laser can alter the shape of the prostate and cause periprostatic, fibrosis making the bladder neck and posterior dissections more difficult. These patients should be offered other treatment until a program has achieved a plateau on its learning curve. A large median lobe can also cause problems with dissection for a less experienced team. Preoperative ultrasound, computerized tomography (CT), or cystoscopic assessment may be considered in patients with severe lower urinary tract symptoms (LUTS) to rule this out.

7.6. The First Case and the Mentor/Proctor

The proctor/mentor and surgeon relationship is very important. We will use these terms interchangeably but some feel that mentorship implies a longer-term relationship with more give-and-take and sharing of surgical responsibility, while the role of proctor is less involved and more observational. We feel strongly that most institutions starting a program will benefit from and require a mentorship relationship at the beginning of their experience. Mentors should have extensive experience performing the procedure, as well as teaching the procedure, in our view at least 100 cases. It is important for the surgeon and the mentor to have a thorough discussion about the steps of the procedure prior to the operation. Ideally, the surgeon should visit the mentor's institution and observe cases being performed by the mentor and team prior to the first cases. Considerations regarding exact technique, sequence of steps, approach and method of vascular control should be agreed upon beforehand. Ideally, arrangements should be made for the mentor to assist at the patient side or console during the operation in order to demonstrate proper techniques.

We believe that it is advisable to perform initial cases using the intraperitoneal approach. The reduced working space using the extraperitoneal approach may negatively impact the initial cases of a new robotic team.

7.7. Review of Reported Results

Reports from other institutions have detailed aspects of their results in comparing their initial experience with laparoscopic prostatectomy with a more recent experience with robotic-assisted laparoscopic prostatectomy.[6,7] While the details of their training are not reported, it is clear that each group was skilled in performance of the laparoscopic procedure and was able to make a relatively easy transition to the robotic procedure by virtue of their understanding of the fundamentals of laparoscopic surgery, their familiarity with the steps of the procedure, and the relevant pelvic anatomy. For these groups addition of the robot was the addition of a sophisticated laparoscopic tool to a procedure they were already very familiar with. Groups with this level of previous experience are likely to have a shorter learning curve.

7.8. Other Thoughts

This raises the question of deciding when a team is trained. Typically groups will feel accomplished when a certain time parameter is reached, usually four hours. While this is an important milestone it is clearly not the most important clinical outcome. The most important parameters are cancer control continence, urinary control, preservation of potency return to normal activities, and freedom from complications. These outcomes take a longer time to realize and are therefore not focused at the time of the initial surgeries. It is critical that these outcomes be monitored so that teams can evolve their techniques over time to achieve optimal results. Recording of cases should be performed to allow teams to review cases and outcomes that are optimal and suboptimal. Modifications and improvements should result from these reviews.

The point at which a team achieves adequacy, comfort, and mastery of the technique will vary with the team's skills and with the team's previous level of accomplishment with open prostatectomy. Teams with superior skills and results may take several hundred cases to reliably exceed results obtained with open surgery, while less proficient open surgical teams may achieve better results with far fewer cases.[8]

The issue of credentialing is raised with any new procedure. Ultimately, this is an issue for local hospitals and, at times, medical societies, to decide. However, these groups have an interest in protecting the public and their patients by giving them the highest standard of care possible. With this in mind, we feel that teams should make patients aware of their level of experience, their training, and their results. It must be realized that medicine is not an exact science and results cannot be guaranteed, even in the most experienced hands. Hospitals should set a standard that assures their patients that they will be well taken care of by physicians who have adequate experience — or are mentored by physicians who have adequate experience — to perform the operation safely and effectively.

Finally, the opportunity for remote proctoring and mentoring is an exciting prospect made possible by the possibility of interface between da Vinci® systems. Live video feed can be observed by a remote surgeon/mentor who can direct a team during performance of a case. Ultimately, the possibility exists for a teaching console to be placed adjacent to the primary operating console or at a site far distant from the operating console. This would allow the mentor to temporarily take over portions of the case to demonstrate particular portions of the procedure.

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8

Patient Selection and Perioperative Management

Gregg E. Zimmerman, Khurshid A. Guru, Hyung L. Kim, and James L. Mohler

Robotic surgery is rapidly gaining popularity throughout the United States. Increasing numbers of hospitals are offering robotic procedures for a variety of indications. Surgical patients, especially those considered higher risk, benefit from the minimally invasive nature of robotic surgery.

Contraindications to robotic surgery are the same as those for laparoscopic procedures. The only absolute contraindication is increased intracranial pressure. Relative contraindications, because exaggerated Trendelenburg position is required, include severe cardiac disease, severe emphysema or other chronic respiratory disease, glaucoma, or history of stroke or cerebral aneurysm.[1]

8.1. Preoperative Period

All patients are evaluated within a month of surgery by the urology and anesthesia services, at which time a complete history and detailed physical examination is performed. Inguinal and umbilical hernias are sought because they can be repaired at the time of the robotic procedure. Surgical scars from previous abdominal operations or trauma may indicate significant intraabdominal adhesions. Surgical technique and potential benefits and risks are reviewed. Complications unique to robotic and minimally invasive surgeries should be described, including air embolus and shoulder discomfort secondary to referred diaphragmatic irritation by residual intraabdominal carbon dioxide. Early ambulation and pulmonary exercise are emphasized to minimize the risk of anesthesia and exaggerated Trendelenburg.

Operative risk is estimated according to the preoperative American Society of Anesthesiology (ASA) classification.[2] Patients with significant cardiac history or symptomatology are scheduled for preoperative cardiology clearance. Those with history of significant lung disease or respiratory symptoms are evaluated by a pulmonologist. For patients undergoing cystectomy with urinary diversion, enterostomal therapy consultation is obtained. Most patients are admitted to the ambulatory surgery unit on the day of surgery, where an intravenous (IV) line is placed, and fluids and antibiotics are started. A blood type and screen is drawn, when appropriate.

8.2. Intraoperative Considerations

Robotic radical prostatectomy, radical cystectomy, and distal ureterectomy are all performed with the patient in exaggerated Trendelenburg and the abdomen insufflated with carbon dioxide gas to 15 mm Hg. Some patients may become hypotensive from diminished venous return to the heart. The physician may lessen the angle of Trendelenburg and/or incrementally decrease the amount of insufflation in an attempt restore blood pressure and continue the operation. Of course, the presence of an acute process such as hemorrhage must be considered.

Pneumothorax must be suspected if oxygen saturation declines. Intraoperatively, breath sounds are evaluated and the diaphragm is inspected. The presence of a bulging diaphragm suggests significant pneumothorax, which can be confirmed with chest X ray. If diagnosis is made visually in a clinically stable patient, the pneumothorax can be managed expectantly because carbon dioxide pnemothorax will resolve over two hours.[3] Otherwise, a small chest tube is inserted and the operation continues.

8.3. Robotic Radical Prostatectomy

Radical prostatectomy is recognized as the gold standard surgical treatment for localized prostate cancer.[4] The invasive nature of radical surgery with its resultant side effects and impact on quality of life has influenced many patients to seek alternate forms of treatment.[5–7] Guillonneau and Vallancien have shown that laparoscopic prostatectomy is possible.[8] However, this minimally invasive alternative to open surgery is a technically demanding procedure with a learning curve that is unacceptable for most urologists.[9] The da Vinci® robot (Intuitive Surgical Inc., Sunnyvale, CA) has been shown to significantly shorten the laparoscopic learning curve.[10,11] Several studies comparing open and robotic radical prostatectomy have reported advantages for the robotic method, including decreased operative blood loss, less postoperative pain, and shorter hospital stay, while maintaining similar oncologic outcomes and complication rates.[9,12]

8.3.1. Patient Selection

The indications for robotic radical prostatectomy are identical to those for open or laparoscopic radical prostatectomy. However, there is a learning curve that should influence case selection for as few as 20 to 25 cases in some series to as many as 150 cases.[13,14] Although there are no anatomic contraindications that apply solely to robotic radical prostatectomy, there are some cases that may prove more difficult. These cases include patients with previous androgen deprivation therapy, previous transurethral resection of the prostate (TURP) or open simple prostatectomy, history of prostatitis, morbid obesity, large prostates, median lobes, or previous abdominal or pelvic surgery.[1] Surgeons may be more selective regarding which cases they perform robotically at the beginning of the learning curve. As experience is gained, these factors become less important considerations.

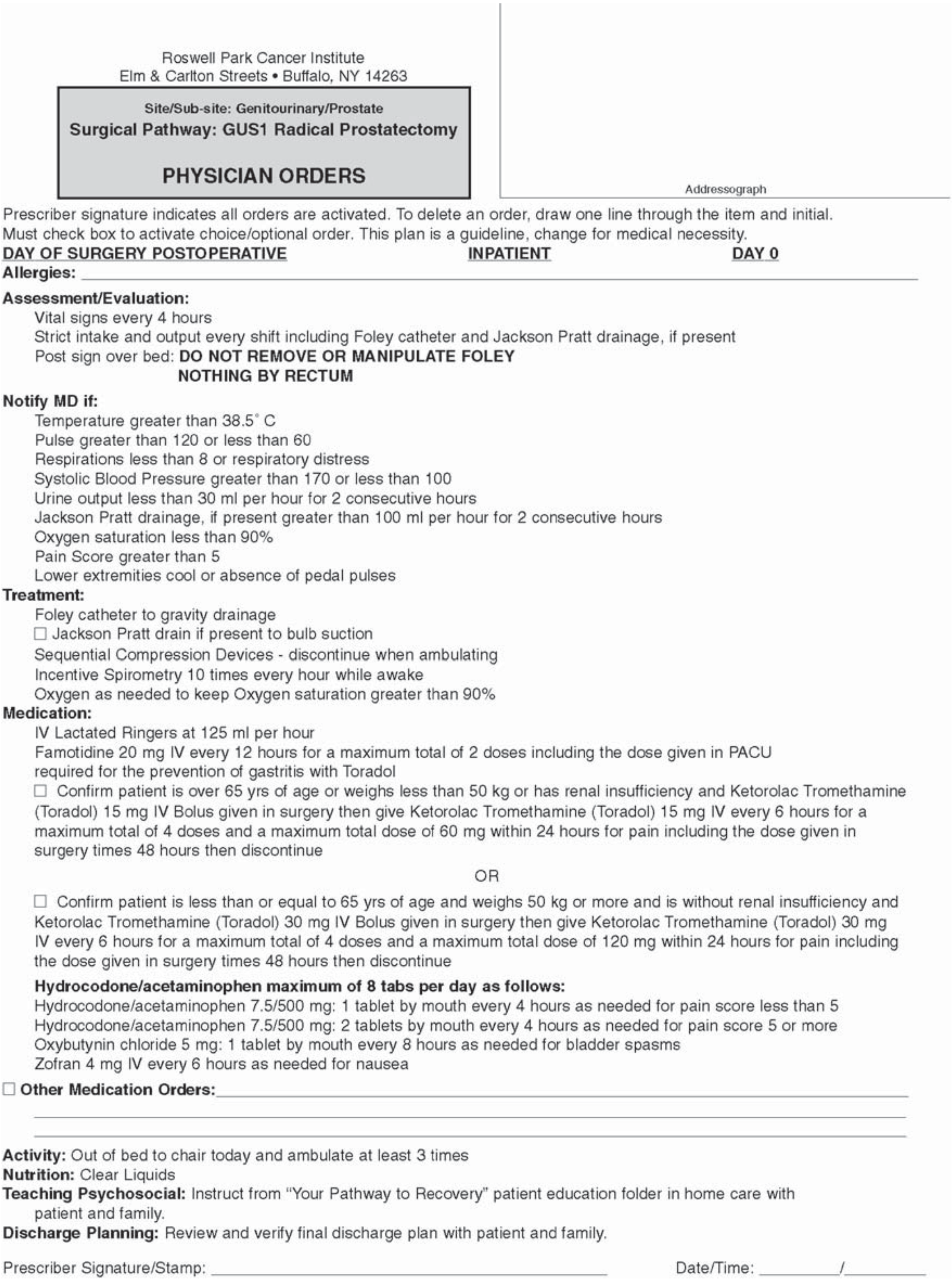
An excellent gauge of increasing operative skill is the ability to handle obesity. Obesity, defined as a body mass index (BMI = weight in kilograms/height in square meters)[15] greater than 30 kg/m^2, is a major health issue in the United States with a rising trend documented over the past 30 years.[16] Ahlering and colleagues reported that obese patients undergoing robotic prostatectomy had significantly worse baseline urinary and sexual function, greater risk of developing significant complications, and did not recover urinary function as quickly or as well as nonobese patients.[17] Although robotic prostatectomy was limited to men less than 100 kg early in our experience, men up to 135 kg with BMI 37.4 have been treated robotically.

8.3.2. Preoperative Period

Patients undergoing robotic radical prostatectomy proceed along a common pathway with few exceptions (Roswell Park Cancer Institute Robotic Radical Prostatectomy Pathway). Patients eat a clear liquid diet the day prior to surgery and take nothing by mouth after midnight. On the morning of surgery, patients take an enema for bowel preparation.

8.3.3. Postoperative Period

Following surgery, standard preprinted order forms are used [see Day Of Surgery Postoperative and Day Of Discharge forms (Figures 8.1 and 8.2). Patient specific variations in postoperative care are identified by open checkboxes, which are filled in by the physician. Sequential compression devices are worn, except when the patient is ambulating. All patients receive IV fluids, ranitidine for ulcer prophylaxis, ketorolac for pain prophylaxis, oral analgesics as needed for pain, oxybutynin as needed for bladder spasms, promethazine as needed for nausea, and diphenhydramine as needed for sleep. Patients may have sips of liquids in the immediate postoperative period. They receive assistance getting out of bed into a chair and ambulating, and are encouraged



Roswell Park Cancer Institute
Elm & Carlton Streets • Buffalo, NY 14263

Site/Sub-site: Genitourinary/Prostate
Surgical Pathway: GUS1 Radical Prostatectomy

PHYSICIAN ORDERS

Addressograph

Prescriber signature indicates all orders are activated. To delete an order, draw one line through the item and initial. Must check box to activate choice/optional order. This plan is a guideline, change for medical necessity.

DAY OF SURGERY POSTOPERATIVE **INPATIENT** **DAY 0**

Allergies: ______________________________

Assessment/Evaluation:
Vital signs every 4 hours
Strict intake and output every shift including Foley catheter and Jackson Pratt drainage, if present
Post sign over bed: **DO NOT REMOVE OR MANIPULATE FOLEY**
NOTHING BY RECTUM

Notify MD if:
Temperature greater than 38.5° C
Pulse greater than 120 or less than 60
Respirations less than 8 or respiratory distress
Systolic Blood Pressure greater than 170 or less than 100
Urine output less than 30 ml per hour for 2 consecutive hours
Jackson Pratt drainage, if present greater than 100 ml per hour for 2 consecutive hours
Oxygen saturation less than 90%
Pain Score greater than 5
Lower extremities cool or absence of pedal pulses

Treatment:
Foley catheter to gravity drainage
☐ Jackson Pratt drain if present to bulb suction
Sequential Compression Devices - discontinue when ambulating
Incentive Spirometry 10 times every hour while awake
Oxygen as needed to keep Oxygen saturation greater than 90%

Medication:
IV Lactated Ringers at 125 ml per hour
Famotidine 20 mg IV every 12 hours for a maximum total of 2 doses including the dose given in PACU required for the prevention of gastritis with Toradol

☐ Confirm patient is over 65 yrs of age or weighs less than 50 kg or has renal insufficiency and Ketorolac Tromethamine (Toradol) 15 mg IV Bolus given in surgery then give Ketorolac Tromethamine (Toradol) 15 mg IV every 6 hours for a maximum total of 4 doses and a maximum total dose of 60 mg within 24 hours for pain including the dose given in surgery times 48 hours then discontinue

OR

☐ Confirm patient is less than or equal to 65 yrs of age and weighs 50 kg or more and is without renal insufficiency and Ketorolac Tromethamine (Toradol) 30 mg IV Bolus given in surgery then give Ketorolac Tromethamine (Toradol) 30 mg IV every 6 hours for a maximum total of 4 doses and a maximum total dose of 120 mg within 24 hours for pain including the dose given in surgery times 48 hours then discontinue

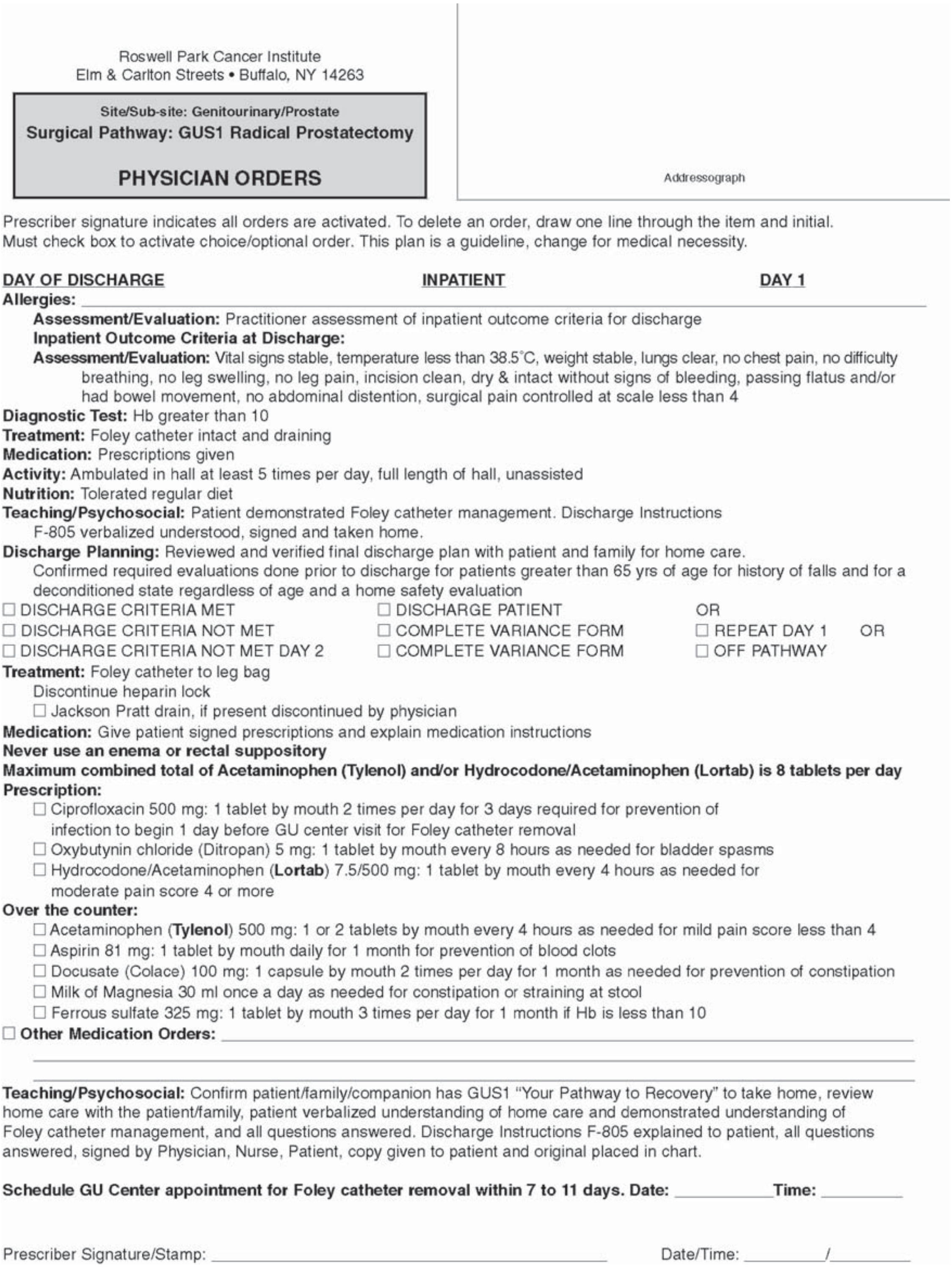
Hydrocodone/acetaminophen maximum of 8 tabs per day as follows:
Hydrocodone/acetaminophen 7.5/500 mg: 1 tablet by mouth every 4 hours as needed for pain score less than 5
Hydrocodone/acetaminophen 7.5/500 mg: 2 tablets by mouth every 4 hours as needed for pain score 5 or more
Oxybutynin chloride 5 mg: 1 tablet by mouth every 8 hours as needed for bladder spasms
Zofran 4 mg IV every 6 hours as needed for nausea

☐ **Other Medication Orders:** ______________________________
____
____

Activity: Out of bed to chair today and ambulate at least 3 times
Nutrition: Clear Liquids
Teaching Psychosocial: Instruct from "Your Pathway to Recovery" patient education folder in home care with patient and family.
Discharge Planning: Review and verify final discharge plan with patient and family.

Prescriber Signature/Stamp: ______________________________ Date/Time: __________/__________

FIGURE 8.1. Day of surgery orders.



Roswell Park Cancer Institute
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Site/Sub-site: Genitourinary/Prostate
Surgical Pathway: GUS1 Radical Prostatectomy

PHYSICIAN ORDERS

Addressograph

Prescriber signature indicates all orders are activated. To delete an order, draw one line through the item and initial. Must check box to activate choice/optional order. This plan is a guideline, change for medical necessity.

DAY OF DISCHARGE **INPATIENT** **DAY 1**

Allergies: ______________________________

Assessment/Evaluation: Practitioner assessment of inpatient outcome criteria for discharge

Inpatient Outcome Criteria at Discharge:

Assessment/Evaluation: Vital signs stable, temperature less than 38.5°C, weight stable, lungs clear, no chest pain, no difficulty breathing, no leg swelling, no leg pain, incision clean, dry & intact without signs of bleeding, passing flatus and/or had bowel movement, no abdominal distention, surgical pain controlled at scale less than 4

Diagnostic Test: Hb greater than 10
Treatment: Foley catheter intact and draining
Medication: Prescriptions given
Activity: Ambulated in hall at least 5 times per day, full length of hall, unassisted
Nutrition: Tolerated regular diet
Teaching/Psychosocial: Patient demonstrated Foley catheter management. Discharge Instructions F-805 verbalized understood, signed and taken home.
Discharge Planning: Reviewed and verified final discharge plan with patient and family for home care. Confirmed required evaluations done prior to discharge for patients greater than 65 yrs of age for history of falls and for a deconditioned state regardless of age and a home safety evaluation

☐ DISCHARGE CRITERIA MET ☐ DISCHARGE PATIENT OR
☐ DISCHARGE CRITERIA NOT MET ☐ COMPLETE VARIANCE FORM ☐ REPEAT DAY 1 OR
☐ DISCHARGE CRITERIA NOT MET DAY 2 ☐ COMPLETE VARIANCE FORM ☐ OFF PATHWAY

Treatment: Foley catheter to leg bag
Discontinue heparin lock
☐ Jackson Pratt drain, if present discontinued by physician

Medication: Give patient signed prescriptions and explain medication instructions
Never use an enema or rectal suppository
Maximum combined total of Acetaminophen (Tylenol) and/or Hydrocodone/Acetaminophen (Lortab) is 8 tablets per day

Prescription:
- ☐ Ciprofloxacin 500 mg: 1 tablet by mouth 2 times per day for 3 days required for prevention of infection to begin 1 day before GU center visit for Foley catheter removal
- ☐ Oxybutynin chloride (Ditropan) 5 mg: 1 tablet by mouth every 8 hours as needed for bladder spasms
- ☐ Hydrocodone/Acetaminophen (**Lortab**) 7.5/500 mg: 1 tablet by mouth every 4 hours as needed for moderate pain score 4 or more

Over the counter:
- ☐ Acetaminophen (**Tylenol**) 500 mg: 1 or 2 tablets by mouth every 4 hours as needed for mild pain score less than 4
- ☐ Aspirin 81 mg: 1 tablet by mouth daily for 1 month for prevention of blood clots
- ☐ Docusate (Colace) 100 mg: 1 capsule by mouth 2 times per day for 1 month as needed for prevention of constipation
- ☐ Milk of Magnesia 30 ml once a day as needed for constipation or straining at stool
- ☐ Ferrous sulfate 325 mg: 1 tablet by mouth 3 times per day for 1 month if Hb is less than 10

☐ **Other Medication Orders:** ______________________________

Teaching/Psychosocial: Confirm patient/family/companion has GUS1 "Your Pathway to Recovery" to take home, review home care with the patient/family, patient verbalized understanding of home care and demonstrated understanding of Foley catheter management, and all questions answered. Discharge Instructions F-805 explained to patient, all questions answered, signed by Physician, Nurse, Patient, copy given to patient and original placed in chart.

Schedule GU Center appointment for Foley catheter removal within 7 to 11 days. Date: ___________ **Time:** _________

Prescriber Signature/Stamp: ______________________ Date/Time: _________/_________

FIGURE 8.2. Day of discharge orders.

to perform incentive spirometry 10 times per hour while awake. Rarely, a Jackson Pratt drain (JP drain) is inserted intraoperatively and, when present, it is placed on bulb suction.

The patient is evaluated the afternoon of surgery and the morning of postoperative day 1. Diet is advanced to regular, and patients are encouraged to ambulate and perform incentive spirometry. The nursing staff reviews the postoperative pathway in detail and most patients are discharged home after lunch on postoperative day 1. Prior to discharge from the hospital, patients are provided with written discharge instructions, which review activity limitations, postoperative medications, emergency contacts, and date and time for a future clinic appointment.

Patients are evaluated in the clinic 7 to 11 days postoperatively, at which time the Foley catheter is removed and a voiding trial is performed. Physical exam concentrates on the incisions for potential incisional hernias. The next clinic visit occurs eight weeks from the date of surgery and includes a review of urinary continence and erectile function, prostate-specific antigen (PSA) level, and urinalysis. The follow-up regimen is planned according to risk, which is dictated by the final pathology and postoperative PSA.

8.4. Robotic Radical Cystectomy

Radical cystectomy with urinary diversion is the standard of care for high-grade, muscle-invasive bladder cancer.[18] The advent of various types of continent urinary diversion has had a significant impact on quality of life.[19] Minimally invasive surgery has become the favored approach for several urologic procedures, but laparoscopic surgery in the narrow confines of the human pelvis is associated with a steep learning curve, which can make this approach to radical cystectomy difficult and time consuming.

The introduction of robotic surgery has diminished these limitations and allowed robot-assisted radical cystectomy to be performed in a safe and efficient manner. Bladder removal and precise extended lymph node dissection can be performed with minimal blood loss. When constructing an orthotopic neobladder, robotic assistance ensures a watertight urethral–neobladder anastomosis. A protocol for peri-operative care has been developed that is divided into preoperative, operative, and postoperative periods.

8.4.1. Preoperative Period

The benefits of minimally invasive surgery for muscle-invasive bladder cancer may be greatest for elderly patients in whom risks are greater for exaggerated Trendelenburg position and increased anesthesia time. In the elderly, basal functions of the organ systems are affected less than the ability to cope with stress.[20] Particular attention to cardiac and pulmonary reserve is required when considering robotic radical cystectomy, especially in the elderly. In addition, the prevalence of psychological distress is high in patients with a new diagnosis of bladder cancer; proper intervention may influence recovery.[21] Finally, the bowel preparation recommended depends on preoperative assessment of bowel function. Most patients require a low residue, clear liquid diet for 24 h and magnesium citrate at 3 PM of the day prior. Elderly patients and those with constipation may require more thorough bowel preparation.

8.4.2. Day of Surgery

Initial evaluation may include a new set of electrolytes if bowel preparation was more extensive, as this can cause significant dehydration. Epidural anesthesia controls pain and prevents ileus. Intraoperative epidural blockade may inhibit protein breakdown after cystectomy, accentuate the stimulating effect of parental alimentation on total body protein, and reduce postoperative morbidity and mortality.[22] Intraoperative upper body warmed air huggers prevent hypothermia. Insensible fluid losses are reduced with robotic compared to open radical cystectomy due to a closed abdominal cavity, but benefits are not yet proven.[23,24] Decreased blood loss, less pain due to a smaller incision and minimal stretch on abdominal muscles, and decreased insensible fluid losses may lead to quicker return to the normal activities of daily living and better quality of life.

8.4.3. Intensive Care Unit Monitoring

Historically, patients undergoing radical cystectomy were admitted to the intensive care unit

Table 8.1. Indications for postoperative surgical intensive care unit (SICU) admissions.[25]

Preoperative evaluation	ASA I & ASA II (FLOOR)	ASA III & ASA IV (SICU)
Intraoperative evaluation	No intraoperative complication (FLOOR)	Intraoperative Complication (SICU)
Postoperative greater evaluation	APACHE II less than or equal to 12 (STEP DOWN)	APACHE II than 12 (SICU)

postoperatively. Multiple studies have advocated routine transfer to the regular surgical floor because patients who spend time in intensive care units are more likely to have prolonged hospitalization.[24] Patients who need intensive care monitoring can be selected using objective criteria. Dahm and colleagues published an algorithm for admission to the intensive care unit see Table 8.1.[25,26]

8.4.4. Postoperative Care

Nasogastric tubes have been advocated to avoid postoperative complications such as nausea, vomiting, aspiration, wound dehiscence, and intestinal anastomosis leak. However, numerous studies have reported that omission of nasogastric tubes and early feeding provides quicker recovery of bowel function. For example, Inman and colleagues studied 430 patients who underwent radical cystectomy and urinary diversion and reported that gastric decompression was associated with prolonged gastric recovery and hospitalization.[27] The use of ketorolac in the early postoperative period reduces use of narcotic analgesics and promotes early return of bowel function.[28]

8.5. Robotic Distal Ureterectomy with Reimplantation

Indications for robotic surgery will expand to a broader range of surgical procedures as experience is gained. For example, robotic distal ureterectomy with reimplantation is offered to patients with distal ureteral tumors who are candidates for open distal ureterectomy. Relative contraindications include prior pelvic irradiation, previous ureteral surgery, and significant retropeitoneal fibrosis.

8.5.1. Preoperative Period

Preoperatively, ureteroscopy and imaging are critical for defining the extent of disease and for choosing ureterectomy versus nephroureterectomy. A standard peri-operative pathway has not been developed because ureteral malignancies are relatively uncommon. Surgical consent includes robotic distal ureterectomy with reimplantation, possible psoas hitch, possible Boari flap, possible nephrectomy, and possible conversion to open.

8.5.2. Intraoperative Considerations

Review of radiographic films during surgery helps define the location of the tumor. The proximal ureteral margin should be sent for frozen section. Excision of a bladder cuff should be performed routinely as the risk of recurrence in a remaining ureteral stump is approximately 30%.[29]

8.5.3. Postoperative Period

Patients are admitted to the floor and started on intravenous fluids and oral liquids. Diet is advanced to regular on postoperative day 1. Patients are placed on acetaminophen every 6h and offered oral narcotics as needed and IV morphine for significant breakthrough pain. Incentive spirometry and ambulation are encouraged. Sequential compression devices are worn when not ambulating. Typically, discharge home occurs on the first postoperative day.

The Foley catheter is left for 10 days, the ureteral stent is removed after six weeks, and the reimplant is examined radiographically after six months. Future cancer surveillance depends on pathology and prior history.

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9

Anesthetic Considerations and Management

Christopher L. Yerington and Barry Nuechterlein

The advancement of surgery into the digital and computer-assisted era has generated a new amalgamation of known anesthetic challenges. This chapter is designed to provide both surgeons and anesthesiologists with a quick reference, guiding optimal peri-operative care in patients receiving robotic urologic surgery. In addition, information critical to ensuring patient safety when utilizing computer-assisted surgical techniques is discussed.

The patient population served in most robotic urologic surgeries where computer assistance is being utilized consists of males, aged 45 to 75 years old, ideally with minimal physiologic perturbations due to underlying disease. Laproscopic considerations mostly revolve around the effects of insufflation of the abdominal cavity and the surgical site being less accessible than during open procedures. Robotic and positioning considerations would include the critical importance of maintaining patient paralysis and the physiologic implications of placing a patient in a high degree of Trendelenburg's position. Generally, the patient's recovery is similar to that of all patients receiving laproscopic surgery and adequate pain management is easily achieved by utilizing multiple modalities (see Figure 9.1).

9.1. Patient Population

In order to provide adequate anesthesia for these procedures, an awareness of the nature of the patients involved is imperative. Males, aged 45 to 75 years old, have a variety of predictable medical issues of concern to the anesthesiologist. In western societies, the prevalence of obesity, diabetes, hypertension, underlying coronary artery disease, and/or peripheral vascular disease necessitates obtaining an adequate history and physical. Ideally, this should be accomplished prior to the day of surgery to ensure any laboratory or functional data can be collected, reviewed, and acted upon.

For example, obesity and hypertension have increasing prevalence with advancing age.[1] Based on data collected in 1999 and 2000, the U.S. National Center for Health Statistics (NCHS) reported in 2003 that 30.1% of men aged 45 to 54 are obese, 32.9% of men aged 55 to 64 are obese, 33.4% of men aged 65 to 74 are obese, and 20.4% of men aged over 75 are obese. Similarly, the same publication reports 36.9% of men aged 45 to 54 have hypertension, 50.7% of men aged 55 to 64 have hypertension, 68.3% of men aged 65 to 74 have hypertension, and 70.7% of men aged over 75 have hypertension. Although nothing can be done about a patient's obesity on or near the date of surgery, a patient's hypertension can be medically optimized prior to surgery.

Obesity presents a variety of direct and indirect challenges to the anesthesiologist.[2] In addition to its contribution to hypertension, coronary artery disease, and diabetes, obesity has direct physical and physiologic implications in patients receiving computer-assisted robotic laparoscopic procedures. Most important among these implications are the effects on pulmonary physiology.[3] When a patient with a large volume of abdominal contents, adipose mass, and central girth is placed in

Figure 9.1. Dr. Patel with a patient prepped, draped, and positioned during engagement of da Vinci® robotic system.

steep Trendelenburg's position with a pressurized pneumoperitoneum, a substantial hindrance to normal diaphragmatic excursion can be generated. This hindrance, in addition to the patients' body habitus, creates both a restrictive pulmonary deficit and atelectasis, with its resultant shunting. Hypercapnia can be seen due to the difficulty of achieving adequate minute ventilation and hypoxia secondary to atelectasis-based shunting are examples of the consequences of these physiologic disruptions and must be avoided.

Hypertension is characterized by increased afterload and decreased intravascular volume. Management of anesthesia in the hypertensive patient begins with preoperative evaluation to determine adequacy of blood pressure control, pharmacologic antihypertensive agents utilized, and presence of end-organ dysfunction.[4] The presence of orthostatic hypotension, ischemic heart disease, cerebrovascular disease, peripheral vascular disease, and/or renal dysfunction should be uncovered. The anesthetic plan will need to incorporate adjustments for these disease states. Also, during induction of anesthesia in the hypertensive patient, one should attempt to minimize the duration of laryngoscopy and expect exaggerated blood pressure fluctuations secondary to vasodilation.[5] The anesthesiologist should modify the dosage of volatile anesthetic to control blood pressure and compensate for any changes in patient position.

Postoperative management of the hypertensive patient includes anticipation of hypertension unrelated to pain and its adequate treatment. Continuation of monitoring modalities utilized intraoperatively in the immediate postoperative period enables a prompt response to blood pressure fluctuations. Signs of myocardial ischemia can be concealed by pain medications and overt use of antihypertensive medication. Vigilance must be maintained during the immediate postoperative period.

Diabetes is an illness that can affect a multitude of organ systems and has many predisposing factors.[6] Aside from the principal goals of maintaining good glycemic control and avoiding ketoacidosis and electrolyte disturbances, the anesthesiologist must appreciate the implications of diabetic autonomic neuropathy. Common manifestations of diabetic autonomic neuropathy include orthostatic hypotension, resting tachycardia, and gastroparesis.[6] As mentioned elsewhere, the combination of a pneumoperitoneum and the placement of the patient in a physiologically challenging position will have perturbing effects on hemodynamics. These effects may be greatly exaggerated in the patient with diabetic autonomic neuropathy.

While no consensus exists on how tightly to maintain glycemic control or otherwise optimize medical management of the diabetic patient in the peri-operative period, discussions are ongoing.[7] A recommendation from 1991, published in *Anesthesiology*, is to maintain the blood glucose concentration in the range of 120 to 180 mg/dL.[8] As in many areas of anesthetic management, attempting to maintain a normal physiologic state is always desirable.

There are many specific anesthetic concerns relating to a patient with coronary artery disease and other vascular disease undergoing any surgical procedure requiring general endotracheal anesthesia. There exist a variety of risk factors for coronary artery disease and other vascular diseases. Obesity, hypertension, diabetes, advanced age, smoking, male gender, family history, stress, inactivity, and high cholesterol are widely recognized as predisposing factors for development of such illnesses.[9] Clinicians should be mindful of these issues, as these illnesses influence the risk of anesthesia and surgery. Peri-operative evaluation, planning, and optimization should be conducted in such a manner as to minimize these risks.

To provide adequate anesthesia for these procedures, an awareness of the nature of the patients involved is imperative. The prevalence of obesity, diabetes, hypertension, coronary artery disease, and/or peripheral vascular disease necessitates obtaining an adequate history and physical. Prior to the day of surgery, any laboratory or functional data should be collected, reviewed, and acted upon. These patients have a variety of predictable medical issues of concern to the anesthesiologist.

9.2. Laparoscopic Considerations

Next year, laparoscopic surgery will be entering its third decade of general use. Increasing interest in laparoscopy among general surgeons developed in 1987 after the French gynecologist Mouret performed the first acknowledged laparoscopic cholecystectomy by means of four trocars.[10] Operative laparoscopy has advanced surprisingly since 1990. Laparoscopic surgery is now entering a phase of slower development. Refinements of laproscopic techniques will come as evolutionary changes in instrumentation and practice rather than an inventive revolution.[11] However, computer-assisted robotic surgery utilizing minimally invasive techniques is rapidly developing towards real-time remote surgery. Clearly, this represents a revolutionary development with extensive implications for the anesthesiologist.

The pulmonary physiologic consequences of intraperitoneal insufflation include decreased compliance, decreased functional residual capacity, and increased shunting due to atelectasis.[12] Principal complications include subcutaneous emphysema, pneumothorax, gas embolism, and cephalad shift of the diaphragm, resulting in inadvertent endobronchial intubation. Because carbon dioxide (CO_2) is the most common gas utilized for insufflation, it is appropriate to discuss its physiologic peculiarities. These include CO_2 absorption, resulting in hypercapnia; potential vasodilation (including cerebral vasodilation); increased metabolism; and increased likelihood of spontaneous respirations in spite of adequate depth of anesthesia.[12]

The cardiac and hemodynamic effects of pneumoperitoneum include decreased cardiac output, elevation of arterial pressures or systemic vascular resistance, and increased pulmonary vascular resistance. It is important to note that decreases in cardiac output are proportional to the increase in intraabdominal pressure.[13] There is some evidence that cardiac output changes little with intraperitoneal insufflation. However, when this is coupled with steep Trendelenburg's position, most studies show a fall of between 10% and 30% in cardiac output.[14] The decrease in cardiac output is secondary to decreased venous return from caval compression and dependent venous pooling. This decrease can be somewhat mitigated by normalizing the circulating volume prior to insufflation, or by utilizing less Trendelenburg's position.

An additional physiologic concern during laparoscopic procedures, particularly those of long duration performed in steep Trendelenburg's position, is the effect of positioning and abdominal insufflation on the nervous system generally and intracranial pressure (ICP) specifically. In patients with ventriculoperitoneal (VP) shunts, it is important that the clinician be attentive to function of the shunt postoperatively, as shunt malfunctions in the wake of surgical pneumoperitoneum have been reported.[15] If a patient is suspected of having elevated intracranial pressure, insufflation of the abdomen (with likely resultant increase in central venous pressure and decreased cerebral perfusion pressure) can be detrimental.[16]

Generally, American Society of Anesthesiology (ASA) standard monitoring is adequate for most computer-assisted robotic laparoscopic procedures. If the nature of the procedure or patients condition warrant placement of invasive monitoring, it should be strongly considered. The reason it should be considered prior to any robotic surgical intervention is because the patients position relative to the robot precludes easy placement of these monitors during the procedure. Additionally, it should be appreciated that there might be no opportunity to achieve better vascular access for resuscitation or monitoring after starting the robotic portion of the procedure (see Figure 9.2).

The recommended anesthetic technique for most laparoscopic procedures, especially those involving a great deal of head-down positioning, involves endotracheal intubation during general

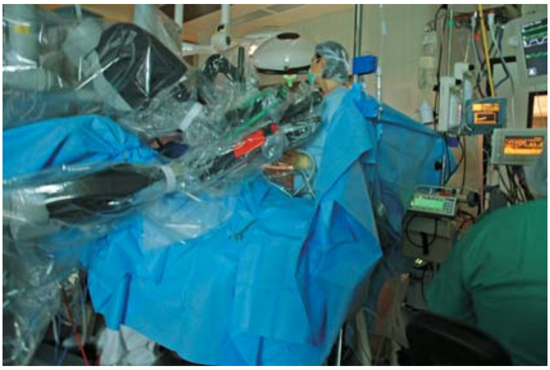

FIGURE 9.2. Depiction of patient undergoing computer-assisted robotic prostatectomy with very limited patient access.

anesthesia. According to a report from the Centers for Disease Control (CDC), one third of the deaths associated with a subset of laparoscopic procedures (tubal ligations) in the period from 1977 to 1981 were related to anesthetic complications during anesthesia without intubation.[17] Given the limitations of positive pressure ventilation in a relaxed patient without an endotracheal tube, attempting to administer anesthesia without one in this context seems daunting. Also particularly important during robotic procedures involving trocars fixed to a stationary device, the patient must *always* remain adequately relaxed.[18] In subsequent portions of this chapter, there will be further discussion of one method of ensuring complete and reliable relaxation during these procedures. A variety of agents may be used to achieve adequate amnesia, analgesia, and relaxation. Nitrous oxide may cause distention of bowel, presenting added technical difficulty in intestinal surgeries, but its use has not otherwise been shown to generate substantial clinical disadvantage.[19]

In summary, laparoscopic techniques result in multiple benefits to the patient, including reduced trauma and postoperative pain, quicker recovery, and overall shorter hospital stays. While many types of procedures can benefit from laparoscopic techniques, minimally invasive urologic surgery seems to have surprising benefits compared to open techniques. The death rate during operative laparoscopy is 1 per 1000 cases; the incidence of hemorrhagic or visceral injury–related complications is approximately 3 per 1000. General anesthesia with controlled ventilation seems to be the safest technique for operative laparoscopy.[20]

9.3. Robotic/Positioning Considerations

There are some substantial differences between conventional laparoscopic surgery and computer-assisted robotic laparoscopic surgery. A discussion of those differences provides useful illumination to improve the clinician's understanding of this latter group of procedures. In addition, pictorial references are helpful when describing robotic and positioning considerations. These differences include challenges relating to patient access, the critical importance of adequate and sustained relaxation through the entire robotic phase of the procedure, and the challenges of physically securing and protecting the patient to prevent sliding or shifting when the robot is engaged. The photographs to follow are from a computer-assisted robotic prostatectomy, during which a steep Trendelenburg position was utilized.

As mentioned above, it is imperative that both the surgeon and the anesthesiologist understand the importance to patient safety of adequate and sustained relaxation during the computer-assisted robotic portion of the procedure. This is a paramount concern for the following reasons: (1) the daVinci® system (Intuitive Surgical Inc., Sunnyvale, CA) employs several fixed trocars, so patient movement can result in serious trauma to major vascular and visceral structures; (2) disruption of the magnified surgical field and/or surgical activity with even the smallest patient movements can prove disastrous; and (3) preservation of delicate pelvic structures such as the autonomic plexus surrounding the prostate cannot be reliably achieved in a moving patient.[21] The anesthesiologist should consider the use of an infusion of muscle relaxant during robotic surgery, particularly if access to the patient for train-of-four monitoring is limited.

Although many drugs are suitable in this context, atracurium and cisatracurium have a substantial advantage. They both have predictable chemical breakdown by Hoffmann elimination (which does not rely on either intact hepatic or renal function), so their action will be reliably terminated after a reasonably short interval.[22] This remains true even in the face of inadvertent overdosage. It should be considered acceptable for a small number of patients to remain intubated and sedated for a short while in the recovery area. Intensive care unit (ICU) admission is rarely indicated because of paralysis if these drugs are utilized. Good communication concerning patient relaxation between surgical and anesthetic personnel is crucial, given the gravity of the potential complications should relaxation prove inadequate.

The following is an example of appropriate infusions for a hypothetical 70-kg male patient. Cisatracurium doses of 0.15 to 0.20 mg/kg ($3 \times ED_{95}$–$4 \times ED_{95}$) yield excellent relaxation for intubation in 90 to 120 s.[22] During induction, a 70-kg male would receive 10.5 mg to 14.0 mg of cisatracurium. Recovery from this initial bolus will be expected between 20 and 30 min. It is recommended that an infusion of 1.0 to 2.0 mcg/kg/min (70–140 mcg/min in our 70-kg male) be initiated within 10 min of this initial bolus to maintain adequate relaxation if train-of-four can be monitored. Cisatracurium is reliably and completely eliminated by Hoffman elimination in all patients so there is no reason to wait for recovery from the initial dosing before beginning the infusion. If the clinician cannot functionally and reliably monitor train-of-four in the patient secondary to insufficient access, a higher infusion of 2.5 to 3.0 mcg/kg/min is recommended for maintenance of relaxation until the robotic portion of the procedure is completed. A suitable regimen can also be devised utilizing atracurium, which shares many of the same properties of cisatracurium. Atracurium generally has a faster onset of action and termination of action compared to cisatracurium, and is also associated with greater histamine release (see Figure 9.3).

FIGURE 9.3. Cisatracurium infusion.

Positioning during computer-assisted robotic urologic surgery is crucial for patient safety. To protect the patient from the robotic device requires planning and knowledge of the procedure to be completed. Sometimes the robot is positioned to the side of the patient, limiting access to the head and airway, and other procedure require it to be place at the foot of the bed reaching over the patient.[23] Either way, the key point is that once the robot is positioned and engaged, little can be done to change a patient's position.

9.4. Recovery/Pain Control Issues

Minimally invasive surgery has many benefits in the area of postoperative pain control and recovery. It has been clearly shown that patients receiving procedures of this type have shorter hospitalizations and lower overall pain levels than with equivalent open procedures.[24] Available modalities for pain control include intravenous opioids, intramuscular opioids, oral opioids, adjunctive nonopioid analgesic medications, and catheter-delivered local anesthetics (see Figure 9.4).

FIGURE 9.4. Placement of On-Q® Pain Pump (I-Flow Corp., Lake Forest, CA) for infusion of local anesthetics postoperatively.

No single opioid is superior and any modality of treatment must be selected based upon the individual patient's specific requirements and sensitivities to medications. As demonstrated by the small size of the incisions in Figure 9.4, a small proportion of the pain involved in these procedures is somatic in origin. Most pain in the first 24 h is visceral in origin, and is well controlled by opioids and other pharmacologic interventions. Regional (neuraxial) modalities, with their attendant risk of complications, may also be utilized in those rare patients with high opioid tolerances, but are unnecessary for most patients.

9.5. Conclusion

This chapter has provided both surgeons and anesthesiologists with a quick reference, guiding optimal peri-operative care in patients receiving robotic urologic surgery. Information critical to ensuring patient safety when utilizing computer-assisted surgical techniques has been discussed. The patient population has been explored and laproscopic considerations have been reviewed. Extensive discussion concerning specific robotic issues and patient positioning were touched upon. Minimally invasive surgery generally offers superior recovery with much reduced pain. The advancement of surgery into the digital and computer-assisted era creates new anesthetic challenges, for which a useful road map has been provided.

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10

Patient Positioning for Robotic Urologic Procedures

Robert I. Carey and Raymond J. Leveillee

Advances in robotic-assisted laparoscopic surgery have exponentially increased since the introduction of the da Vinci® Surgical System (Intuitive Surgical Inc., Sunnyvale, CA). "Robotic" surgery has become more prevalent in many centers of surgical excellence around the world. The radical retropubic prostatectomy for treatment of prostate cancer has become a focal point of experience for robotic-assisted operations in the pelvis. The most common robotic-assisted renal operation has been the dismembered pyeloplasty. Although necessary long-term follow-up of these procedures has not yet been achieved, it is becoming increasingly apparent that robotic technology is changing the standard of care for complex urologic procedures. In this chapter, we describe logistical issues pertaining to patient positioning for these two most commonly performed urologic operations. Emphasis will be placed on patient and staff safety issues, ergonomics, and optimizing surgical exposure.

Proper positioning of the patient is a necessary first step for robotic-assisted laparoscopic procedures. Without proper patient positioning and port placement, robotic-assisted procedures are tedious to perform and patient outcomes are compromised. Obtaining the proper patient position is a dynamic process that requires the supervision of the surgeon. Not only should the patient be protected from injuries, but the optimal position must allow safe docking of the robot, as well as access for the bedside surgeon to the surgical assistant ports. This chapter will focus on the major points for positioning and port placement for the most common robotic-assisted urologic procedures. We will describe the positioning related to robotic-assisted laparoscopic renal procedures (pyeloplasty) as well as procedures in the pelvis (radical prostatectomy, pelvic lymph node dissection, ureterovesical re-implants).

10.1. Robotic-Assisted Laparoscopic Prostatectomy

For a robotic-assisted laparoscopic prostatectomy (RALP), patients are ultimately positioned in the supine position in a steep Trendelenburg incline, as shown in Figure 10.1. Initially, a compression hose and sequential compression devices are placed prior to the induction of general anesthesia for venous thromboembolism prophylaxis. Positioning starts with the table horizontal to the floor (neutral position) and the patient flat/supine with the buttocks at the end of the table break. The caudal end of the table is then lowered until it is perpendicular to the plane of the table. The legs are placed in Allen stirrups (Allen Medical Systems, Acton, MA) with the knees flexed and lowered so as not to interfere with the docking of the robot. Individual gel pads are placed bilaterally from the shoulders to the hips to minimize trauma at pressure points. The patient is held into position with a desufflated "bean bag" (Olympic Vac Pac, Olympic Medical, Seattle, WA).

The elbows and wrists are positioned in such a way as to allow slight flexion, with the fingertips ideally situated on the anterolateral thigh. The arms are tucked at the side of the patient. One

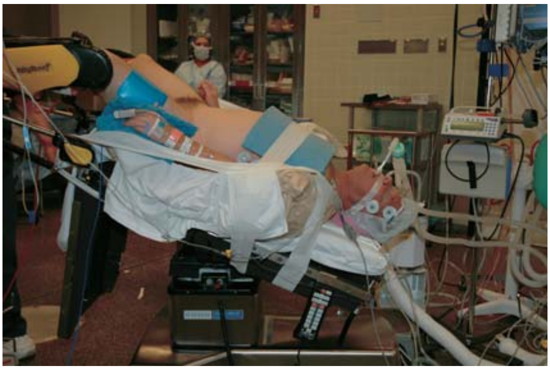


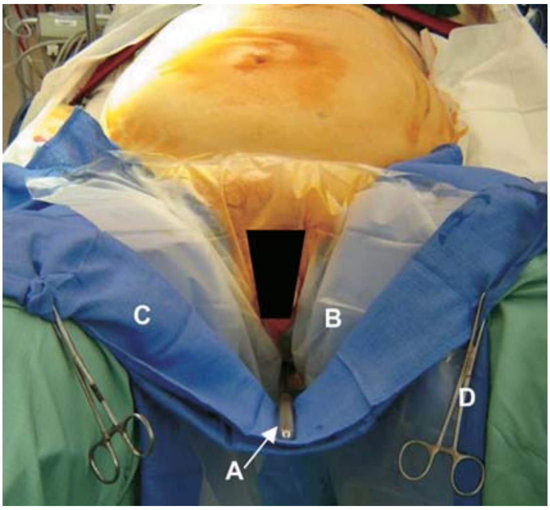
Figure 10.1. To ensure the stability of the patient and to allow anesthesia to check all lines and tubes, the patient is placed in steep Trendelenburg position prior to draping.

[redacted]

Figure 10.2. The patient fully positioned in supine postion, ready to be draped prior to a robotic-assisted laparoscopic radical prostatectomy.

should avoid placing the arms perpendicular to the chest (like a crucifix) in order to avoid injury to the brachial plexus. The elbows and wrists are protected with foam padding with slight bend at the elbow and wrist. The arms should be kept low at the side of the patient in order to avoid contact with the lateral working arms of the robot. This is especially important when using a four-arm robotic system. Although the lateral most trocars will be placed medial to the anterior superior iliac spine (ASIS), the patient's arms should be placed in a position that allows the prepped field to be lateral to the ASIS. Three-inch cloth tape is used to further secure the bean bag to the cranial and caudal ends of the table. The chest is secured with the placement of a horizontal three-inch tape, as well as Velcro straps. The legs should be placed into their low lithotomy position prior to draping to ensure that the knees are flexed and properly angulated. At this point the stability of the patient in steep Trendelenburg should be tested, as seen in Figure 10.1. This allows a thorough inspection of all pressure points and allows the anesthesia team to visualize the extent to which the patient will be positioned once the drapes are applied. Once the patient is draped, small movements of the patient may go unnoticed. The shoulders should be fixed and well padded. The head should be stable. A picture of a positioned patient ready to be prepped is shown in Figure 10.2.

The patient is prepped from the mid-epigastrium to the genitalia and mid-thigh, including the perineum. Leg drapes are placed followed by a 3M$^{\text{TM}}$ Steri-Drape$^{\text{TM}}$ Urological Drape 1071 (3M Company, St Paul, MN) with a rectal bougie that is held in place with towel hammock secured to each leg, as seen in Figure 10.3. A 16 Fr, 10-mL Foley catheter is inserted on the field. The field is established for the bedside assistant to have access to the perineum for intraoperative rectal and urethral manipulation. The abdominal drapes are placed and a Mayo stand can be used



[redacted]

Figure 10.3. The rectal bougie (A) is passed into the rectum through the condom of the 3M$^{\text{TM}}$ Steri-Drape$^{\text{TM}}$ Urological Drape 1071 (3M Company, St Paul, MN) (B). This is held in place by a towel hammock (C) that is fixed with two clamps (D) to the leg drapes.

to protect the face and the endotracheal tube. An orogastric tube is placed and no nitrous oxide is used with the general anesthesia.

Multiple views illustrating the preferred trocar locations are shown in Figure 10.4(A–C). Prior to docking the robot, the patient should be in approximately 20° to 30° Trendelenburg position. The robot is brought in for docking between the legs of the patient, as seen in Figure 10.5. Once docking occurs, the optimal fulcrum for the point of rotation for the robotic instruments has been achieved. Table tilt or rotation is not feasible, nor is it safe, at this time.

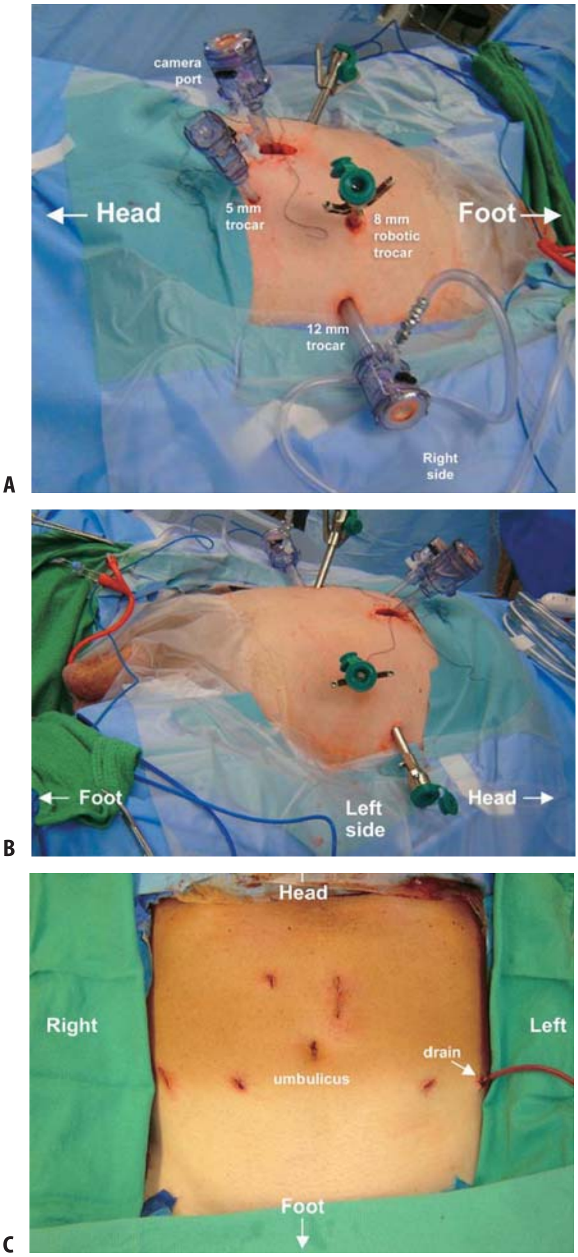


Figure 10.4. (A) The arrangement of trocars seen on the right side of the patient. (B) The left side of the patient. (C) An overhead view of the trocar arrangement at the completion of the case after all sites have been closed.

Figure 10.5. The docking of the robot between the legs of the patient.

Some authors have stated a preference for the handedness of the surgical assistant at the bedside to dictate the side of the table, left-handed assistants standing on the right side of the table and right-handed assistants on the left.[1] The advantage stated is that the assistant is able to use the dominant hand to control the suction port with the assistant in a comfortable sitting position. In our experience, the bedside assistant has typically been an experienced (right-handed) laparoscopic surgeon, standing on the right side of the table.

10.2 Robotic-Assisted Laparoscopic Ureterovesical Reimplant

The positioning required for a ureterovesical reimplant is similar to that for a transperitoneal radical prostatectomy, as both procedures are performed in the deep pelvis. However, a ureteral reimplant requires dissection of the ureter superiorly in the abdomen in order to gain mobility of the ureter. The distal dissection of the ureter and the ureterovesical anastomosis are performed inferiorly on the same side of the pelvis. Depending on the length of the stricture, preparation for a Boari flap may be required. The most convenient position for docking the robot is between the patient's legs when they are in low lithotomy. A more optimal placement would be with the main pedestal of the robotic platform in direct line with the inguinal ring on the ipsilateral side, however, the operating table pedestal and the support structure of the robotic platform prevent proper proximity to each other. Adequate positioning can be achieved, however, with the platform placed as with the prostatectomy operation. The fully positioned patient being tested for stability in Trendelenburg position and ready to be prepped is illustrated in Figures 10.6 and 10.7.

For mid-ureteral injuries where a uretero-ureterostomy is planned, it may be helpful, prior to beginning the robotic-assisted reimplant, for the patient to undergo cystoscopy with placement of ipsilateral ureteral catheter secured to a Foley catheter. This can be achieved on the transporting gurney if desired. Alternatively, a retrograde pyelogram may be desired. For distal ureteral strictures where ureteroneocystotomy is planned, this step can be omitted.

Positioning is started with the patient supine and is done as previously described for a radical prostatectomy. The ureteral catheter and Foley catheter are prepped into the field. Insufflation of the abdomen is obtained using a Veress needle at the site of the intended camera port, 1 cm superior to and 5 mm lateral to the umbilicus on the contralateral side of the abdomen to the reconstruction. The robotic arm ports are placed 9 to 10 cm distant from the camera port and triangulated with the camera port directed to the ipsilateral lower quadrant at the site of the anticipated re-implant. The working ports are adjustable around the camera port depending on the level, proximal or distal, of the ureteral injury. The robot is preferentially docked between the patient's legs as it is not possible to bring the robot over the flexed legs in stirrups. The patient is placed in steep Trendelenburg position prior to docking of the robot. It is not safe, nor is it possible to reposiition the bed once the robot has been docked.

Figure 10.7. View of a patient being tested for positional stability in steep Trendelenburg prior to beginning a robotic-assisted laparoscopic ureteral re-implant.

Figure 10.6. View of a patient ready to be prepped for a robotic-assisted laparoscopic ureteral re-implant.

10.3. Kidney Surgery

10.3.1. Transperitoneal Robotic-Assisted Laparoscopic Pyeloplasty

Before the patient enters the room, we establish the table relationship in the room such that the robot will be pushed in a straight line to the patient for the eventual docking. This requires that the table be angled approximately 45° to the line of the robot, as shown in Figure 10.8.

In our described technique for pyeloplasty,[2] we start our positioning with the placement of sequential compression devices and compression hose. The bed is fitted with a bean bag (Olympic

Figure 10.8. Patient positioning and room configuration prior to right robotic-assisted laparoscopic pyeloplasty.

Vac Pac) from the patient's shoulders to hips. The patient is then intubated and all preoperative lines are placed. The patient is placed into a lateral decubitus position with the ipsilateral side up and the patient at a 45° angle only. Previous to the introduction of surgical robotics we would customarily position the patient between a 45° and 90° angle. A subaxillary role is place at nipple level. The bottom leg is bent at 45° and the top leg is nearly straight with less than 10° flexion. The ankles are wrapped in foam padding and the legs are stabilized with pillows. One assistant holds the ipsilateral arm during the entire positioning procedure. The bean bag is desufflated to make it firm and to conform with the patient's body. The ipsilateral arm is placed into an AMSCO Krause arm support BF10000 (Steris Corp., Mentor, OH). Here is where a major difference exists between standard laparoscopic positioning and robotic-assisted positioning: The ipsilateral arm must lie low and cephalad enough to allow for the midline robotic trocar and working element to be positioned without interference. If the contralateral arm is placed at a 75° to 90° angle it will be in the way. The contralateral arm to the kidney being treated is, therefore, secured at a 45° angle on a flat arm rest. Both arms are carefully padded with foam and secured with flexible bandages. The patient is further secured at the arms, chest, hips, and legs with cross-table 3-inch cloth tape. The bed is tilted fully right and left prior to draping. The final positioning of the patient is illustrated in Figure 10.8.

The lines of robot docking are shown in Figures 10.9(A–C) and 10.10. By predetermining the likely angle for optimal docking, you can avoid cumbersome docking maneuvers and shorten the docking time. The robot is docked with care to avoid any injuries to the head or upper extremities

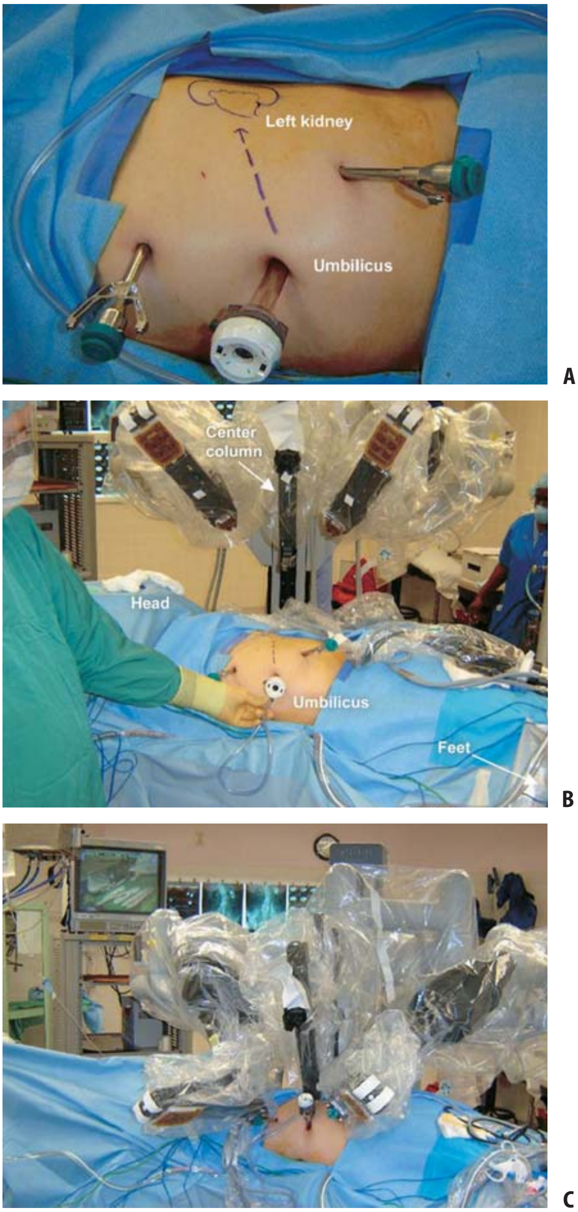


Figure 10.9. (A) Trocar arrangement for a left-sided three-port pyeloplasty prior to docking of the robot. (B) The approach of the robot for docking. (C) The robot docked to the patient for pyeloplasty.

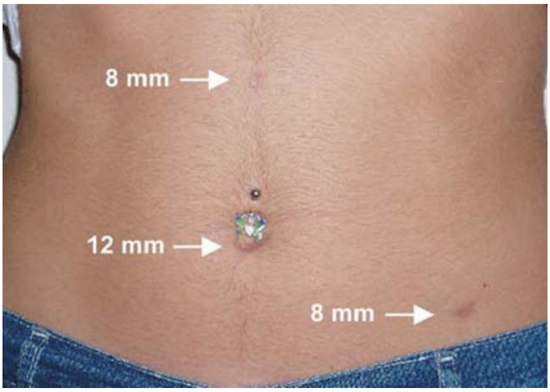


Figure 10.10. Desired cosmesis after three-port robotic pyeloplasty.

of the patient by the moat superior robotic working unit.

10.4. Conclusion

Positioning of a patient prior to a robotic-assisted laparoscopic surgery is critical to the overall success of the procedure. Once docked, the da Vinci® robot and patient are fixed into a space. Subsequent attempts to reposition may be performed only after the patient is undocked from the robot to prevent serious injury. In order to fully appreciate the advantages afforded by the da Vinci® robot, the patient must be favorably positioned with the port placement guided by an experienced surgeon. Unfavorable positioning or port placement will lead to frustration, increased operative times, and inferior outcomes.

We have presented our preferred positioning and setup for the most common robotic-assisted procedures. Adaptation and alteration may be made based on the individual surgeons' preference and judgment.

Acknowledgment. We thank Ms. Pamela Roza for preparing the illustrations for this chapter.

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11

Transperitoneal Trocar Placement

Justin M. Albani and David I. Lee

Proper port placement is crucial during conventional laparoscopic surgery. Likewise, during robotic laparoscopic procedures this concept is equally as important. The da Vinci® Surgical System (Intuitive Surgical Inc., Sunnyvale, CA) in its current form consists of a patientside cart with arms that dock to trocars that are preplaced by the surgeon. These arms are rather bulky and require sufficient room to maneuver. An effective port placement situates the arms so that they provide excellent intraabdominal instrument mobility while minimizing arm collisions. This chapter will describe some tips on port placement classified by procedure to help surgeons overcome the learning curve of this preliminary but crucial step to robotic urologic procedures.

11.1. General Considerations

As with conventional laparoscopy, a standardized methodology for trocar placement in robotic-assisted surgery is based on the procedure to be performed, patient habitus, and the location of the target organ.[1] The da Vinci® Surgical System has certain elements that must be understood in order to properly place trocars. The system consists of a surgeon console and the patientside cart. The patientside cart has three or four arms that are sterilely draped with plastic. The arms have an area for a sterile adapter that translates the motion of the surgeon's hands to the movement of the cable-driven laparoscopic instruments. The instruments themselves are attached on the arms via these sterile adapters and then placed into the abdomen through custom robotic trocars. These specially designed 8-mm trocars are reusable and lock precisely onto the working arms of the robot (Figure 11.1). The shafts of the trocars are marked with three black circumferential lines. The middle line, which is indicated by the thickest diameter line, is known as the *remote center*. Once the robot arm is docked to the trocar that has been placed into the abdominal wall, any instrument motions performed by the surgeon are conducted by the robot while maintaining the remote center perfectly still in space. A potential benefit of this fixed remote center kinematics are that side loads on the body wall and, thus, trauma at the point of entry, may be minimized to the point where patients may experience less postoperative pain.

The robot arms themselves are equipped with two buttons that help the operating room (OR) team to move the arms into position. One is known as the *setup joint* button and the other is the *clutch* button (Figure 11.2). Before attempted docking, it is important to place the arms into a neutral position [Figure 11.2(A)]. This is performed with a combination of setup joint and clutch movements. During docking, the arms are maneuvered toward the trocar only with setup joint button moves; this allows the maximum pitch and yaw range of motion and thus provides the greatest intraabdominal mobility of the arms. Once docked, arm mobility is dependent not only on minimizing instrument clashing within the abdomen but also with arm collisions on the outside of the patient. Minimizing these events can be achieved with proper spacing of the arms which begins with proper port placement.

Figure 11.1. Photograph of Intuitive Surgical's proprietary da Vinci® 8-mm working cannula. Note the three black circumferential lines present on the shaft of the trocar and the *remote center* indicated by the thickest diameter middle line.

A key characteristic of the instruments is the maximum working length of 25 cm. This will greatly influence the placement of trocars so that reach of the instrument to the target organ will be facilitated.

After nearly full establishment of pneumoperitoneum, the abdomen should be marked for proper secondary port placement. If the skin is marked before insufflation, the sites will likely end up in markedly different positions after full expansion of the abdomen. Once the ports are marked specifically for the planned case, trocar insertion should be performed using a constant controlled force. We prefer the use of the blunt rather than bladed obturator. These are placed in a similar manner as with other dilating trocars. While placing the trocars, it is very important not place them obliquely through the fascia. A 90° angle to the fascia and skin should be absolutely maintained while placing the trocars. This is especially true in the overweight or obese patient, where an oblique placement of the trocar can result in the holes in the skin and the fascia to be quite displaced from one another (Figure 11.3). This may markedly compromise the robotic arm's mobility. For example, if the robotic trocar is placed so that the hole in the fascia is 2 cm distal from the marked port site of the skin and the remote center mark is placed at the level of the fascia, the arm will behave as if the trocar is

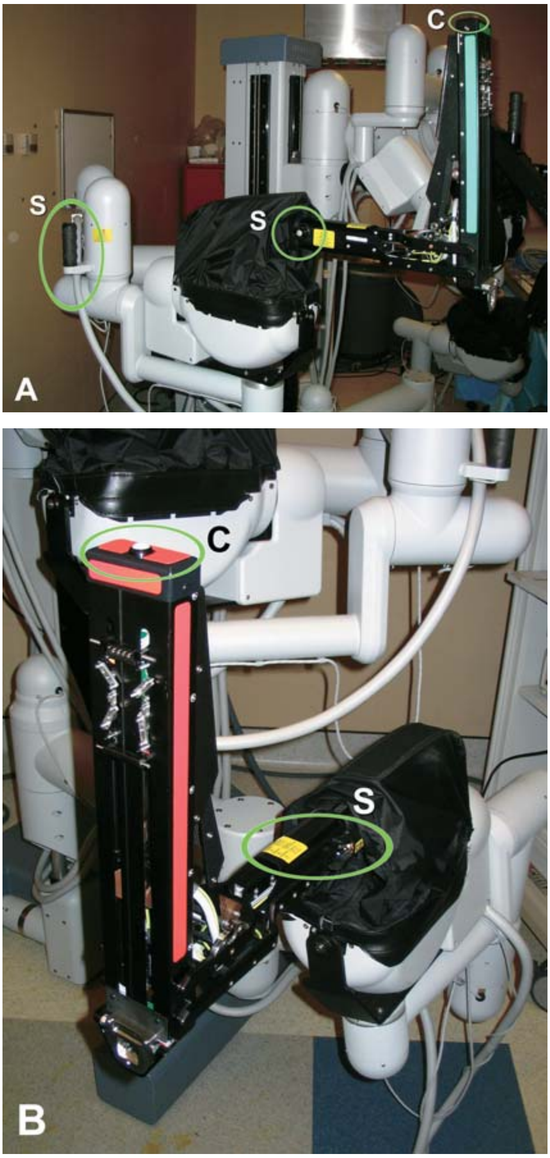

Figure 11.2. Photograph of the *setup joint* button (S) and the *clutch* button (C) present on the robot arms that allow proper arm positioning and docking for the procedure on a standard three-arm surgical system (A) and on the fourth arm of the da Vinci® Surgical System (B). Note the neutral position before attempted docking (A). This position maximizes arm mobility and markedly facilitates the arm attachment to the placed trocars.

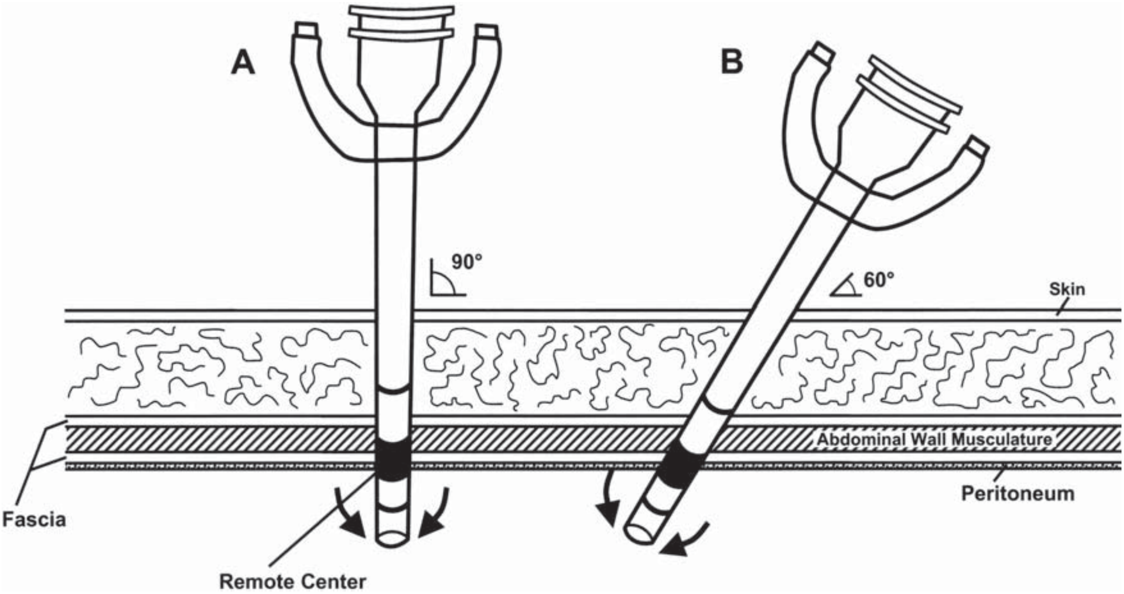

FIGURE 11.3. Correct (A) and incorrect (B) placement of the 8-mm da Vinci® working cannulas. (A) Note the proper location of the fixed *remote center* of the cannula at the peritoneum and the cannula's entry through both the skin and underlying fascia and peritoneum at 90°. This allows for maximum port mobility while minimizing tissue trauma. (B) Incorrect placement results in oblique placement of the trocar and may compromise robotic arm mobility.

2 cm further from site marked. This can be critical when attempting to sew urethral anastomotic sutures if the reach of the instruments is compromised. An easy way to check whether a port is placed in the proper fashion is to view the exterior of the trocar after placement. If properly placed, it will project at nearly a perpendicular direction from the skin. A trocar that appears to be at an acute angle may indeed have a hole in the fascia distant from that in the skin and the subsequent range of motion may be severely limited.

Secondary trocar insertion should be completed under direct vision to avoid injury to any visceral structures after transilluminating the anterior abdominal wall with the light of the laparoscope to avoid vascular injury. This technique usually identifies only the superficial abdominal wall vessels and thus surgeons must have a high suspicion for abdominal wall vascular injury if trocars are placed outside of the avascular midline or medial (less than 6 cm from the midline) to the lateral border of the rectus sheath.[2–4]

11.2. Pelvic Operations (Radical Prostatectomy, Cystectomy, Sacrocolpopexy)

After general anesthesia is induced, the patient is placed on a bed with split leg positioners. Alternatively, Allen (Allen Medical Systems, Acton, MA) stirrups may be used. The legs are abducted approximately 30° and rotated downward roughly 20°. This allows the patientside cart to be moved sufficiently close to the patient as it approaches the patient from the feet. The legs are loosely wrapped with blankets and the arms are tucked. The patient is then placed in an exaggerated Trendelenburg position. We prefer the split leg positioners, as we feel it simplifies patient positioning and may in fact help to prevent slippage of the patient toward the head once in the Trendelenberg position.[5] Typically, six abdominal ports are placed when utilizing the four-arm da Vinci® Surgical System for transperitoneal pelvic surgery or if a three-arm surgical system is utilized with two assistants.[6–8] Alternatively, five abdominal ports are routinely used with a three-arm da Vinci® Surgical System and a single patientside assistant.[5,6,8]

11.2.1. Prostatectomy

Once adequate insufflation has been obtained with a Veress needle off the midline, the trocars are placed as in Figure 11.4, beginning with the midline supraumbilical trocar. Certainly the Hasson approach can be used if preferred.[9]

Previous authors have described secondary port placement for robotic-assisted prostatectomy based on measurements using the umbilicus as a primary external landmark.[6–8] Recognizing the work by Pick and colleagues, we plan port placement based on measurements taken from the pubis; this constant bony landmark can be used as a surrogate for the urethra to measure distances from port sites to ensure adequate arm reach for performing the vesicourethral anastomosis.[10] In this study, the authors determined the maximum distance from the pubis to the working ports should be less than 18 cm to ensure adequate robot arm length.[10] Utilizing the known maximum robotic arm length of 25 cm and measurements of the depth from the skin over the pubis to the membranous urethra based on patients' pelvic computerized tomography (CT) scans and the change in abdominal wall height after CO_2 insufflation, the investigators used the Pythagorean theorem to calculate the maximum distance from the pubis that would consistently provide sufficient arm length for completing the vesicourethral anastomosis.[10] It is our practice to precisely measure the distances for each port rather than estimating by hand width. Initially, a marking pen is used to identify the top of the pubis. A 12-mm mark is placed just above the umbilicus for the camera port. Another mark is placed 15 cm cephalad from the pubis in the midline, as we have found empirically that this distance from the pubis provides even more reliable arm length for completion of the vesicourethral anastomsosis. The two 8-mm robotic working trocars are then located such that they are 8 cm lateral to the midline mark and 15 cm above the marked pubis (Figure 11.4). This ensures sufficient working room between the arms of the robot and enough reach so that the tips of the instruments will reach the urethral stump to enable completion of the vesicourethral

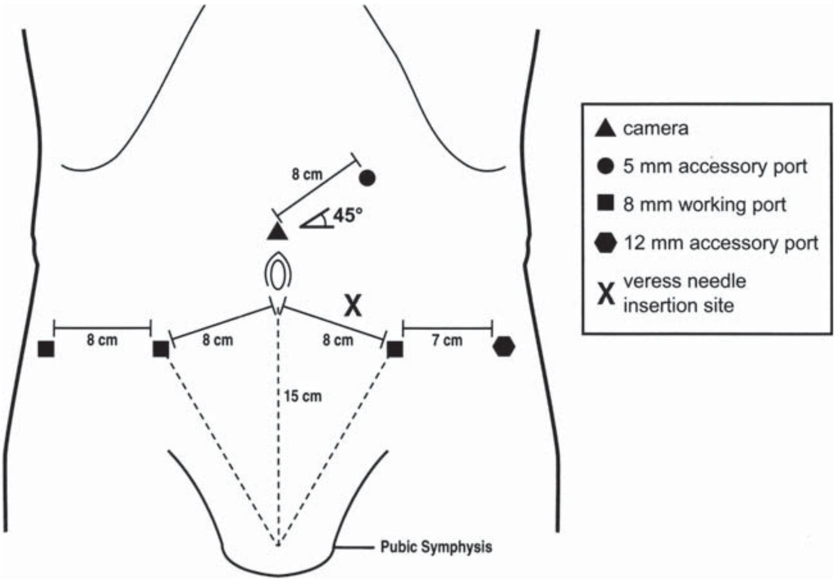

FIGURE 11.4. Port placement for robotic-assisted prostatectomy with a four-arm da Vinci® Surgical System (six-port technique). Note the distance of the primary working ports of 15 cm measured from the pubis and the 8-cm distance between robotic working ports to prevent arm collisions.

anastomosis. Difficulty with arm collisions can become greatly magnified if the trocar sites are too close together. The straight horizontal line created by the first two robotic working ports then allows for further port placement. The straight line is followed 8 cm lateral to the right-hand robotic port for placement of the fourth arm port and 7 cm lateral to the left-hand robotic port for the 12-mm assistant port (Figure 11.4). We place the 12-mm port only 7 cm away to help facilitate placement of the laparoscopic stapler for division of the dorsal venous complex. A 5-mm trocar is placed 8 cm at a 45° angle on a diagonal line cephalad and lateral to the camera port. This can lie very close to the costal margin on smaller patients. This high position is essential to provide adequate working room for the right hand of the assistant, as placement too low can trap the assistant's hand between the robotic arms. It is important to remember that a bariatric length (45 cm) suction tip is necessary to effectively utilize this trocar site. Once ports are placed, the surgical cart is moved into position between the legs of the patient. The camera and yellow and green arms of the surgical cart are brought in over the patient and docked. The red, or fourth, arm is brought underneath the leg of the patient and then raised until it just touches the underside of the leg holder and docked to the lateral working robotic port.

Alternatively, others have described a five-port technique with a sixth optional port if additional access is needed or a second patientside surgeon is present.[6,8] Once adequate insufflation has been obtained with a Veress needle, the trocars are placed as in Figure 11.5 beginning with the midline 12-mm camera trocar either supra- or infra-umbilically, based on the patient's height. The two 8-mm robotic working trocars are then located such that they are symmetrically placed at least 2.5 cm below the level of the umbilicus and just lateral to the rectus muscle. A 5-mm assistant port used primarily for suction and irrigation is placed between the camera port and the right 8-mm working robotic port either 2.5 cm superior to or 7.5 cm inferior to the umbilicus. The fifth port, a 12-mm accessory port, is then placed 2 to 3 cm superior to the right iliac crest along the midaxillary line. An additional 5-mm accessory (sixth) port may be placed on the corresponding contralateral side 2 to 3 cm superior to the left iliac crest if additional retraction is necessary or a second patientside assistant is present.

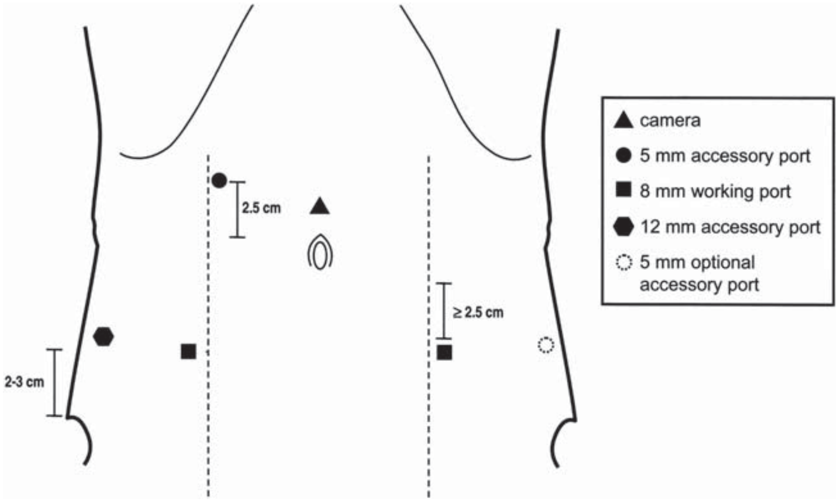

FIGURE 11.5. Port placement for robotic-assisted prostatectomy with a three-arm da Vinci® Surgical System (five-port technique). An optional sixth port (5-mm accessory port) may be placed approximately 2 to 3 cm cephalad to the left iliac crest if additional retraction or a second patientside assistant is available. (Adapted from Hemal et al., Urol Clin North Am 2004;31:683–692, by permission of *The Urologic Clinics of North America*.)

11.2.2. Cystectomy with Orthotopic Ileal Neobladder (Studer) Urinary Diversion

Trocar placement for robotic-assisted radical cystoprostatectomy with an orthotopic ileal neobladder (Studer) is similar to that for robotic prostatectomy with a few important variations.

Once adequate insufflation has been obtained, the trocars are placed as in Figure 11.6, beginning with the midline 12-mm camera trocar placed approximately 3 cm superior to the umbilicus to provide adequate visualization for the urachal dissection. The robotic working ports are placed no more than 18 cm away from the pubis to allow adequate arm reach to perform the neovesical–urethral anastomosis. Additionally, if possible, the ports are spaced out further away from each other (as much as 10 cm apart); this increases the lateral reach of the arms, facilitating the necessary extended pelvic lymphadenectomy and complete proximal mobilization of the ureters. However, these maneuvers may not adequately mobilize the arms and thus undocking of the robot and standard laparoscopic dissection of the ureters may be necessary. Secondary ports can be placed along the same straight line formed by the initial robotic ports with the most lateral fourth arm robotic working port on the patient's right side 8 cm lateral to the adjacent port and the contralateral 12-mm assistant port 7 cm lateral to the other port. The 5-mm accessory trocar is again placed 8 cm at a 45° angle on a diagonal line cephalad and lateral to the camera port.

11.2.3. Cystectomy with Ileal Conduit Urinary Diversion

Trocar placement for robotic-assisted radical cystoprostatectomy with an ileal conduit urinary diversion mirrors that for robotic cystoprostatectomy with an orthotopic neobladder; however, consideration can be given to placing the working trocars slightly more cephalad to facilitate the pelvic lymphadenectomy and ureteral mobilization as a urethral anastomosis is not performed. However, it must be kept in mind that an apical prostate dissection still has to be performed. Additionally, some surgeons may utilize the site

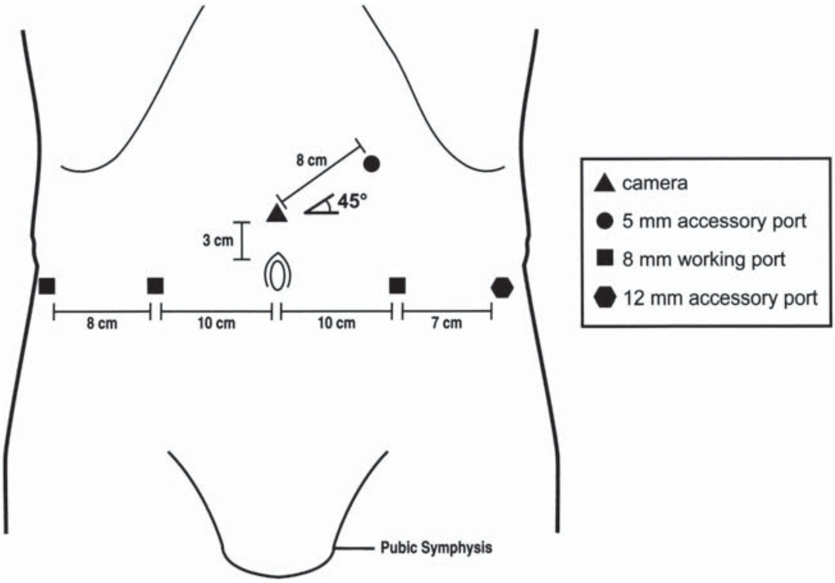

Figure 11.6. Port placement for robotic-assisted cystectomy with ileal orthotopic neobladder (Studer) urinary diversion. Note the 12-mm camera port is placed more cephalad than in the robotic prostatectomy and the working ports are placed more laterally to allow for greater mobility in performing an extended lymphadenectomy and in mobilization of the ureters. The ports are placed at or just below the umbilicus to facilitate reaching the neobladder–urethral anastomosis.

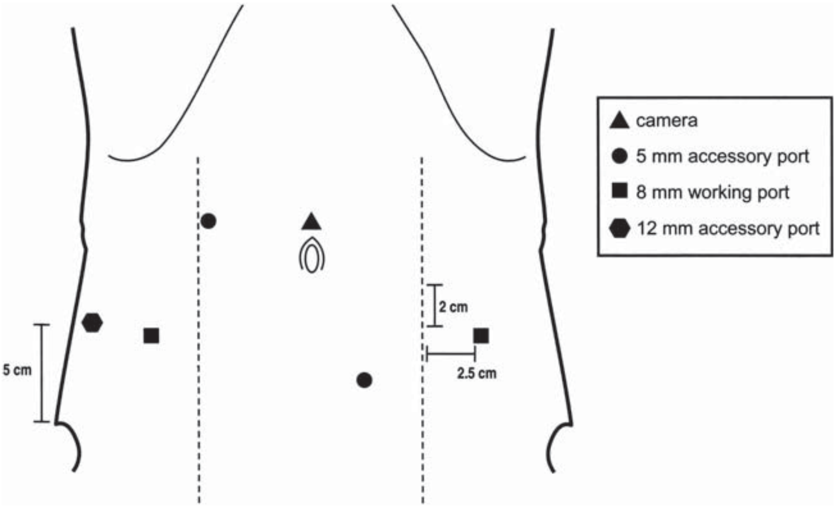

Figure 11.7. Port placement for robotic-assisted cystectomy. Note the greater distance between the primary working ports (2.5 cm lateral to the rectus muscle edge) and more superiorly placed assistant ports (5 cm superior to the iliac crest) facilitates pelvic lymphadenectomy and ureteral mobilization.

of the planned stoma for a port placement if applicable, but this is not requisite.

Many authors have described using an identical standardized port placement for all pelvic surgeries.[6,11–13] Others have published subtle modifications in trocar placement, such as widening the distance between the working ports by placing them 2.5 cm lateral to the rectus muscle and increasing the distance of the assistant ports from the iliac crest to 5 cm to facilitate pelvic lymphadenectomy and ureteral dissection and subsequent reconstruction (Figure 11.7).[14]

11.3. Renal Operations

11.3.1. Transperitoneal Approach

After the induction of general anesthesia and the placement of a Foley catheter, the patient is secured in the lateral decubitus position. We gently flex the bed to open the space between the iliac crest and costal margin and do not elevate the kidney rest.

After sterile preparation and draping the patient appropriately, a 12-mm curvilinear incision around the umbilicus on the side of the surgery is made with a scalpel. The underlying dermis and subcutaneous adipose tissue is transected using cautery until the underlying fascia is reached. After establishing pneumoperitoneum, the ports are placed as in Figure 11.8, beginning with the peri-umbilical trocar as described by Peschel and colleagues.[15] The two 8-mm working ports for the robotic arms are placed under laparoscopic control in a triangular fashion such that one is placed in the upper midline near the xiphoid process and the other is placed at the lateral border of the rectus inferior to the umbilicus. These ports are optimally placed by ensuring at least 8 cm exists between the camera port and each working port to avoid robotic arm collisions during the surgery (Figure 11.8). Many variations exist for placement of the assistant port, ranging from subxiphoid, peri-umbilical, adjacent to the rectus between the camera and working port, infra-umbilical and contralateral to the opposite working port, to even no assistant port at all.[6,13,16–19] We have found that placement of a 5-mm port infra-umbilically along the midline provides excellent mobility for the assistant. Likewise, this port should be at least 8 cm away from the camera port. Sutures needed for pyeloplasty or partial nephrectomy can easily be passed in and out of the 8-mm robotic instrument port, obviating the need for a second 12-mm cannula. In the obese patient, this port placement moves laterally such that the

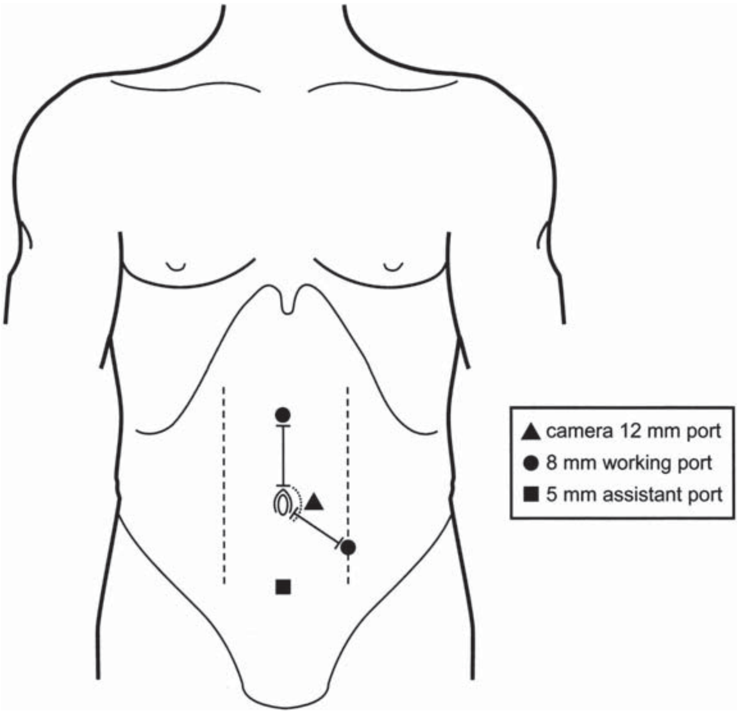

FIGURE 11.8. Port placement for left-sided transperitoneal robotic-assisted renal surgery. A mirror image is used for a right-sided procedure. (Adapted from Peschel et al., Urol Clin North Am 2004;31:737–741, by permission of *The Urologic Clinics of North America*.)

initial 12-mm port is placed in the pararectus line at a level with or just above the umbilicus; the other ports likewise are moved laterally in a similar manner.

11.4. Special Considerations

Tableside assistants for the surgeon must have excellent knowledge of the limitations of the robotic arms, thus allowing easy troubleshooting. If, despite proper trocar placement, the robotic working arms become limited by reach, the assistant may perform a *setup joint release maneuver* to carefully advance the entire robotic arm and port in the needed direction. This requires stabilization of both the port and robotic arm to avoid trauma to the abdominal wall. Careful teamwork between assistant and console surgeon are critical in this maneuver, as movement of the arm by *setup joint* can cause inadvertent intraabdominal injury. Lastly, in patients where reaching the urethral anastomosis remains difficult despite these maneuvers, perineal pressure by the assistant may often prove effective as well.

11.5. Conclusion

Development of optimal trocar placement during robotic-assisted laparoscopy requires experience and an intimate working knowledge of the surgical system. Once port placement becomes reproducible, the later portions of the procedure will be greatly facilitated.

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12

Extraperitoneal Access

András Hoznek, Michael Esposito, Laurent Salomon, and Clement-Claude Abbou

12.1. Introduction

Initial development of laparoscopic radical prostatectomy (LRP) was based on the experience of a few surgeons with transperitoneal laparoscopic access to the prostate and seminal vesicles.[1–3] Transperitoneal laparoscopic radical prostatectomy was successfully introduced in routine clinical practice in France following the pioneering work of Gaston and Piéchaud in 1998 (unpublished series). Transperitoneal approach became predominant worldwide and was considered as the gold standard of laparoscopic prostatectomy.

However, many teams have later reported that opening of the peritoneal cavity is not indispensable and that primary transperitoneal access to the seminal vesicles should not be considered as the key of laparoscopic prostatectomy anymore.[4–7] A growing number of centers worldwide developed their technique of extraperitoneal laparoscopic prostatectomy and many of them have definitively abandoned the transperitoneal approach.[6–13]

But both of these techniques are difficult to learn and teach because of the inherent limitations of laparoscopic surgery.

Feasibility and reproducibility of robotic-assisted LRP has also been described,[14–18] but mostly with transperitoneal approach. Telerobotics provides technical features like three-dimensional (3D) vision, increased robotic instrument maneuverability, and physiologic tremor filtering. These factors are thought to provide an ergonomic environment for the surgeon that simplifies performance of complex laparoscopic tasks. Unfortunately, obligatory close proximity of the laparoscopic ports with transperitoneal robotic radical prostatectomy (RP) can create interference between the robot and conventional instruments used by the assistant.[17]

Given our favorable results with conventional extraperitoneal LRP, we first described the feasibility of extraperitoneal approach using the da Vinci® robotic system (Intuitive Surgical Inc., Sunnyvale, CA) on an initial series of four patients.[19]

12.1.1. Retroperitoneal Access and Trocar Placement

The initial retroperitoneal access was gained by making a midline 3-cm incision, 1 cm inferior to the umbilicus. The subcutaneous tissue was divided down to the anterior rectus fascia. The anterior rectus fascia was then incised transversally to identify the inner borders of the rectus muscles separated by the linea alba. The index finger was introduced medially under the rectus muscle and along the posterior rectus sheath [Figure 12.1(A)]. A blunt finger dissection was performed to create a space extending superiorly from the level of the skin incision to the lateral border of the rectus muscle. This space is limited caudally by the arcuate line of Douglas, posteriorly by the posterior rectus sheath, anteriorly by the posterior fibers of the rectus muscle, and medially by the linea alba. The same step was performed on the other side. At this stage, two

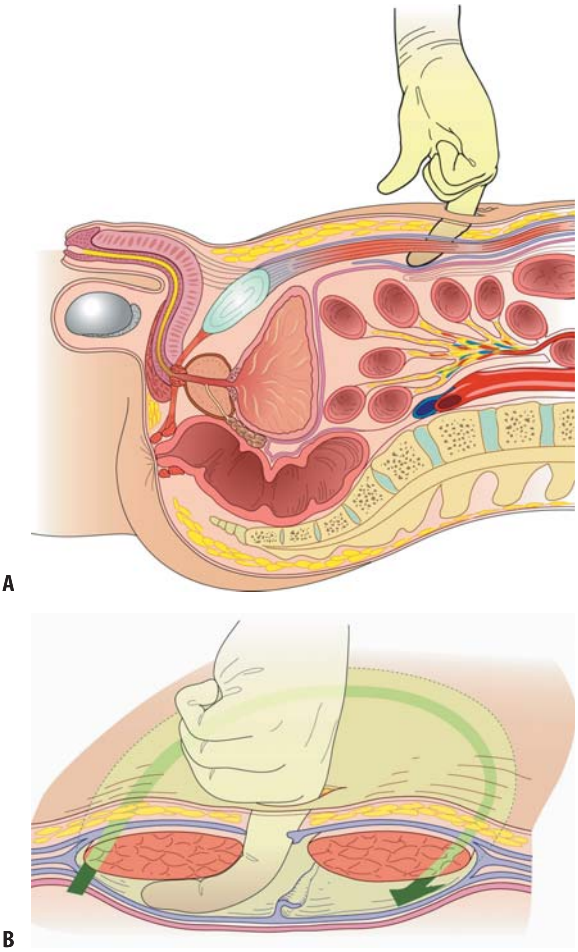

Figure 12.1. Creation of the extraperitoneal working space.

spaces were created under each rectus muscle and separated by the linea alba.

The linea alba was then incised in contact with the anterior rectus fascia. The disruption of linea alba was continued by the index finger as far as possible toward the symphysis pubis. At the end of the blunt finger dissection, a large preperitoneal space is created [Figure 12.1(B)].

A Hasson cannula (Bluntport, US Surgical, Norwalk, CT) was placed and insufflation commenced at 18 mm Hg. Using blunt dissection with a conventional laparoscope, a midline "tunnel" in the Retzius space was developed to the pubis. If available, space creation is greatly facilitated at this stage with a balloon dilatator.

Additional ports were subsequently positioned. For patients one through three, laparoscopic ports were placed as superior as possible in the Retzius space to replicate port placement previously used for transperitoneal robotic RP.[14] For patient four, the working robotic ports were placed 4 cm more distal (Figure 12.2). The patient was placed in a 15° to 20° Trendelenburg position and insufflation pressures were reduced to 12 mm Hg.

12.1.2. Salvage of the Extraperitoneal Space

Occasionally, the extraperitoneal space is lost due to inadvertent peritoneal insufflation that causes it to collapse. The collapse may result from an obvious peritoneal membrane tear, a thinning of the membrane with no apparent breach, or no discernable cause.

When the extraperitoneal space has collapsed, we have been able to re-expand it by decompressing the peritoneum. At this point the peritoneal cavity is typically insufflated, and inserting a 5-mm visible entry trocar provides safe entry into

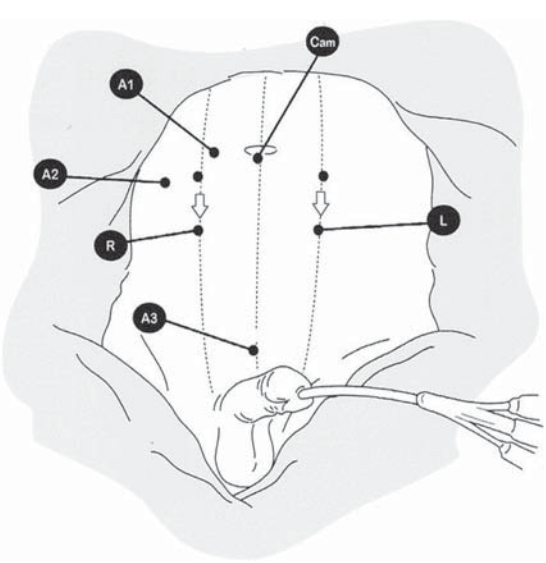

Figure 12.2. Trocar placement (marked dots) during extraperitoneal telerobotic laparoscopic RP illustrating more distal placement of right (R) and left (L) robotic working trocars in comparison to placement of the robotic working trocars with the transperitoneal approach (unmarked dots). Abbreviations: Cam, camera port; A1, assistant port; A2, assistant port; A3, assistant port; R, right extraperitoneal working robotic port; L, left extraperitoneal working robotic port.

the peritoneal cavity for decompression. We have found the Veress needle to be inadequate for this purpose. This trocar allows for either continuous or intermittent venting of the peritonuem.

If the extraperitoneal space cannot be reinsufflated to create adequate space to accommodate trocar insertion or to offer adequate maneuvering space, the surgeon must decide either to proceed or to convert to a transperitoneal approach. Having found that proceeding with less than optimal space is a struggle, we choose the latter option. Conversion to a transperitoneal approach requires that the peritoneal cavity be directly insufflated via the newly inserted 5-mm ventilation trocar. The 12-mm periumbilical camera trocar is removed and reinserted to traverse the peritoneal membrane, which had originally been avoided. Use of two small retractors helps to identify the peritoneum. The four additional trocars must then be repositioned so that they too traverse the peritoneum for clear access to the pelvic anatomy.

12.2. Published Series

In our initial series, no difficulties were noted when developing the extraperitoneal space.[20] All additional steps were successfully performed with telerobotics. More distal placement of the robotic ports appeared to improve the feasibility of the extraperitoneal approach. The peritoneum acted as a natural bowel retractor and the distal port placement facilitated use of the assistant ports. Mean operative time was 274 min (range, 124–360 min). Mean catheterization time and hospital stay were 2.7 and 5.3 days, respectively. A positive margin was observed in one patient and pathological stage was pT2 in three and pT3 in one. No postoperative complications or open conversions were observed.

More recently, these ergonomic advantages were confirmed on a larger series of 154 consecutive patients.[21] Esposito and colleagues used a fourth robotic arm and found that this decreased reliance on highly trained laparoscopic assistants, provided efficient traction and exposure, and allowed a more natural patient position during the operation with smaller degree of Trendelenburg.

The largest experience was reported by Joseph and colleagues, who treated 325 patients with da Vinci® robot–assisted extraperitoneal LRP.[22] Average total operative time was 130 min (range, 80–480 min), mean blood loss was 196 cc, and 1.3% of patients required blood transfusion. Ninety-six percent of patients were discharged from hospital within 8 to 23 h of surgery. Pathological stage was pT2a, pT2b, pT3a, and pT3b in 18%, 63%, 14%, and 5% of patients, respectively. The surgical margin was positive in 5% of pT2a, 11.1% of pT2b, 37.1% of pT3a, and 27.3% of pT3b cases.

12.3. Comment

The extraperitoneal approach for telerobotic laparoscopic RP was successfully performed in growing number of centers worldwide.[19–22] A favorable byproduct of the extraperitoneal approach may be improved port placement for robotic RP. With the transperitoneal technique, all ports are placed essentially on a horizontal umbilical line to facilitate dissection of the seminal vesicles and vas deferens in the pouch of Douglas and to facilitate takedown of the urachus. Although we found a higher trocar insertion was feasible with the extraperitoneal approach, distal trocar placement appeared more efficacious. More distal port placement is possible because the extraperitoneal approach permits direct access to the Retzius space and obviates urachal takedown. Joseph and colleagues use a very similar trocar geometry when performing extraperitoneal robotic prostatectomy.[21,23] The ergonomic advantage is threefold: increasing the working area between laparoscopic and conventional ports, reducing likelihood of instrument collisions, and increasing access to the perineum. In addition, the extraperitoneal approach does not adversely impact laparoscopic geometry, possibly because the telerobotic instruments restore two degrees of freedom not present with conventional laparoscopy.

Besides benefits for robotic prostatectomy, the extraperitoneal approach also provides other advantages.[8,10,11,13,23–25] Access creation in the case of a previously operated abdomen is safer. Postoperative ileus is less frequent. Fluid collections (anastomotic leak, hematoma) are easier to manage. This latter observation is important, especially for those who have limited laparoscopic experience. With direct access to the Retzius space, the peritoneum also functions as a natural bowel retractor, thereby preventing bowel displacement into the surgical field. In our experience, the size of the extraperitoneal space can easily approximate the size of the actual working space used during the transperitoneal approach. In addition, the extraperitoneal approach better approximates the steps of open retropubic RP.

12.4. Conclusion

The extraperitoneal approach for da Vinci®–assisted LRP is a viable alternative. The extraperitoneal robotic approach, using a more distal port placement, appears to permit better access to the prostate and a more coordinated approach between the surgeon and assistant; however, additional clinical experience is warranted. If technical advantages can be proven in a larger series of patients, the extraperitoneal approach could ultimately become the approach of choice for robotic and nonrobotic laparoscopic RP.

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13

Robotic Radical Prostatectomy: A Step-by-Step Approach

Alok Shrivastava and Mani Menon

Radical retropubic prostatectomy is one of the most difficult operations in the field of urology. After the procedure was introduced by Millin in 1947, this technique was adopted by others and modified,[1–5] but never gained widespread popularity because of the significant complications of bleeding, incontinence, and impotence. Although anatomic discoveries by Walsh improved the surgeon's ability to remove all tumor and have substantially improved other outcomes.[1] Open radical prostatectomy still remains a procedure with significant morbidity.[2]

Laparoscopic techniques in other surgical fields heralded an era of minimally invasive surgery with promise of early recuperation and reduced morbidity. Although laparoscopic radical prostatectomy was first described in 1992, the procedure took too long and offered little advantage over conventional retropubic radical prostatectomy.[3] It was only after the pioneering work of Guillonneau and Vallancien,[4] and Abbou and colleagues[5] that there was a resurgence of interest in the procedure. Nonetheless, the consensus among American urologists remained that the procedure was exceedingly difficult to master and offered little benefit to the patient.[6]

In November 2000, Guy Vallancien performed the first robot-assisted radical prostatectomy using the da Vinci® robotic system (Intuitive Surgical Inc., Sunnyvale, CA) at our institution.[7] The procedure was implemented to the routine surgical care of patients with localized prostate cancer in March 2001. As of this writing, we have performed over 2100 cases. Our technique has continually evolved. This evolution is driven by our increasing experience, better instrumentation, newer insights into the prostatic anatomy, and a quest for better functional results.

13.1. Robot-Assisted Prostatectomy: A Step-by-Step Approach

Our initial technique of robot-assisted prostatectomy was based firmly on the scientific foundations of the Montsouris technique of laparoscopic prostatectomy.[7] However, there were important differences between the techniques of robot-assisted and conventional laparoscopic radical prostatectomy. Our modifications were necessitated by the need for separate console and patientside surgeons and subtle considerations for avoiding conflict between the da Vinci® and patientside surgeon's ports. The ergonomics of the movements of the surgeon's fingers had to adapt to the limitations of the robotic instruments and take advantage of their versatility.[8]

13.2. Steps of the Robotic Prostatectomy

A list of instruments used in robotic prostatectomy is listed in Table 13.1.

TABLE 13.1. Instruments used for Robotic Prostatectomy.

Console surgeon	Assistants
Monopolar hook cautery	Microfrance laparoscopic graspers
Bipolar graspers	ACMI Suction irrigator with long suction
Roundtip robotic scissors	Cannula
Robotic needle drivers	Laparoscopic scissors
Long tip grasper	Laparoscopic needle drivers
	Endocatch bag
	Laparoscopic Weck Clip appliers

13.2.1. Development of the Extraperitoneal Space

13.2.1.1. Robotic Instruments

- Right arm: Monopolar Hook Cautery (90 W)
- Left arm: Bipolar Maryland Forceps (25 W)
- Telescope: 30° directed upwards

13.2.1.2. Procedure

The peritoneal cavity is inspected using the 30° upward-looking lens (Figure 13.1). A transverse peritoneal incision is made extending from the left to the right medial umbilical ligament. The incision is extended in an inverted U to the level of the vasa on either side. The extraperitoneal space is developed after transecting the medial and median umbilical ligaments.

Both assistants provide traction/countertraction to facilitate the dissection. This dissection allows the bladder, prostate, and bowel to drop posterior and the remainder of the operation to be performed extraperitoneally. At the end of this step, prostate covered with periprostatic fascia and bladder covered with a layer of fat is seen.

13.2.2. Exposure of Prostatic Apex and Control of Dorsal Venous Complex

13.2.2.1. Objective

The levator fascia near its junction with the lateral prostatic fascia in incised to expose the levator muscle fibers. This frees the lateral attachment of the lateral prostatic fascia and provides space for the dorsal venous stitch.

13.2.2.2. Procedure

13.2.2.2.1. Robotic Instrument Change

- Telescope: 0°

The 0° lens with fine scaling is used for this part of dissection. The levator fascia often has a weak area, through which the levator fibers can be exposed. This fascia is incised using the da Vinci® hook. Dissection is carried inferiorly until the urethra with the surrounding puboperinealis muscle is exposed (Figure 13.2) and superiorly until the prostatovesical junction is identified by the presence of a subtle tongue of retroperitoneal fat (Figure 13.3).

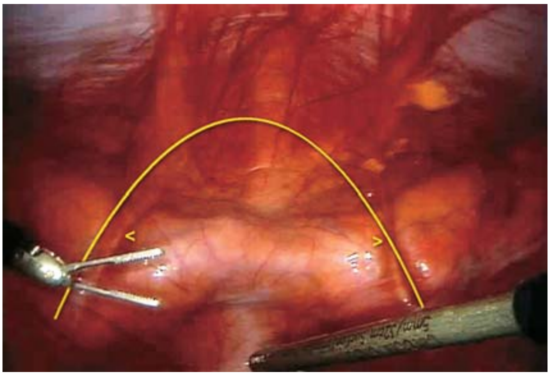

FIGURE 13.1. Development of the extraperitoneal space. The yellow line marks the site of the peritoneal incision, < is the left median umbilical ligament, and > if the right median umbilical ligament.

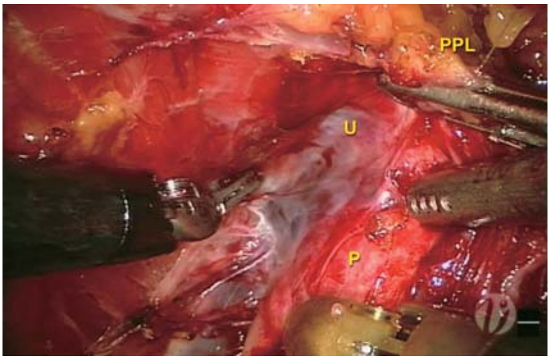

FIGURE 13.2. Inferior extent of dissection of the endopelvic fascia. Abbreviations: U, urethra; PPL, left puboprostatic ligament; P, prostate.

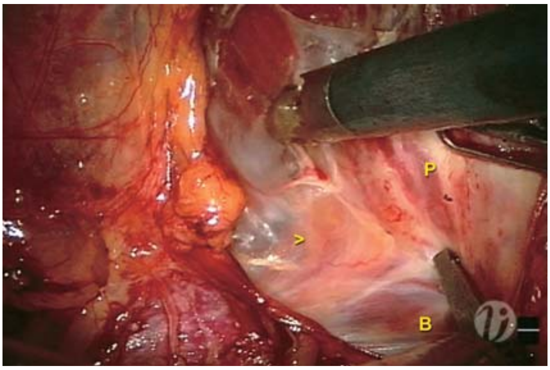

FIGURE 13.3. Superior extent of dissection of the endopelvic fascia. Abbreviations: P, prostate; B, bladder; >, retroperitoneal fat at the prostatovesical junction.

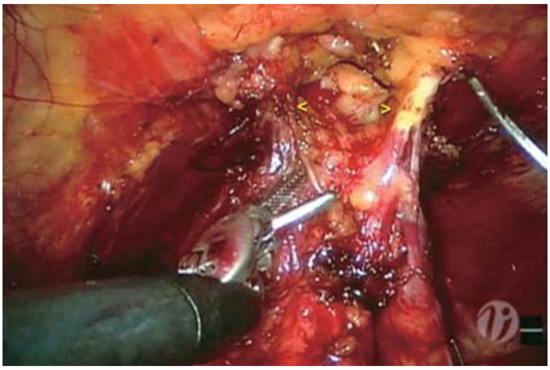

FIGURE 13.5. Second pass of the dorsal vein stitch. Abbreviations: <, left puboprostatic ligament; >, right puboprostatic ligament.

13.2.2.2.2. Robotic Instrument Change

- Right arm: Robotic Needle Driver
- Left arm: Robotic Needle Driver

The nonscaled setting is used for dorsal venous stitch. A 2-0 Vicryl suture on CT 1 needle is used. The first suture is placed to control the dorsal venous plexus. This suture is placed anterior to the external sphincter and posterior to the dorsal venous complex from right to left (Figure 13.4), passing the needle almost horizontally. The stitch is then placed backwards, more superficially, skimming the puboprostatic ligaments, from left to right (Figure 13.5). The stitch secures the dorsal venous complex while maintaining the attachments of the puboprostaic ligaments and the membranous rhabdosphincter.

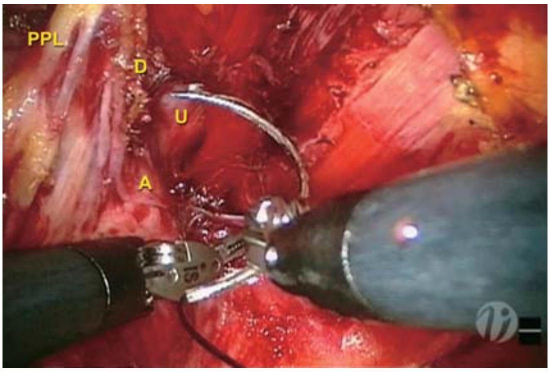

FIGURE 13.4. Start of the dorsal venous stitch. Abbreviations: PPL, right puboprostatic ligament; D, dorsal venous complex; U, urethra; A, prostatic apex.

13.2.3. Bladder Neck Transection

13.2.3.1. Objective

The bladder neck is separated from prostatic base to expose the anterior layer of the Denonvilliers fascia, which is incised to expose the vas deferens and the seminal vesicles. The vasa are cut, the seminal vesicles are dissected. The posterior layer of the Denonvillier's fascia is separated from the posterior prostatic fascia in midline to expose the prostatic pedicles on both sides.

13.2.3.2. Procedure

13.2.3.2.1. Robotic Instrument Change

- Right arm: Monopolar Hook Cautery (90 W)
- Left arm: Bipolar Forceps (25 W)
- Telescope: 30° directed downwards

A 30° lens looking down aids in delineation of the prostatovesical junction. The prostatovesical junction is identified by the natural groove between prostate and bladder. The assistant lifts the anterior bladder wall in midline and the Foley balloon is deflated; this aids in the identification of this junction as the unsupported pliable bladder wall falls posteriorly, draping over the base of prostate (Figure 13.6).

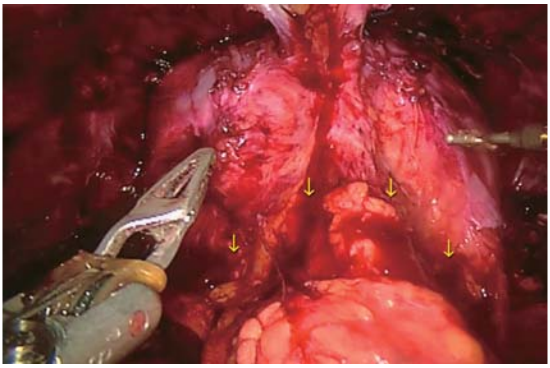

Figure 13.6. Identification of the prostatovesical junction. Abbreviations: ↓, natural groove between prostate and bladder.

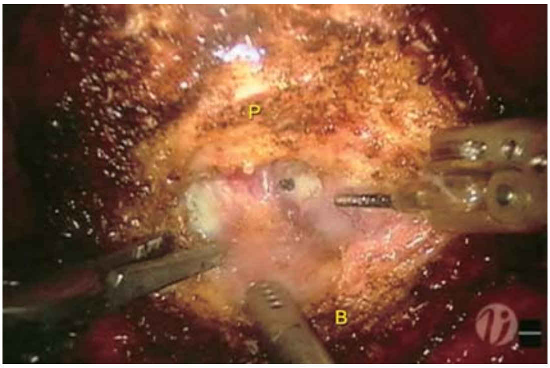

Figure 13.8. Exposure of anterior layer of the Denonvillier's fascia. Abbreviations: P, prostate; B, posterior bladder neck.

The junction is usually at the point at which loose fat can no longer be swept off of the prostate. The bladder neck is incised using an electrocautery hook and 1:3 scaling for adequate coagulation of bleeders. No attempt is made to preserve the anterior bladder neck. Rather, it is incised eccentrically, so that the posterior lip is slightly longer than the anterior lip. This maneuver helps in better visualization of the posterior suture line during anastomosis.

After the anterior bladder neck is incised, the left-side assistant grasps the tip of the Foley catheter with firm anterior traction. This exposes the posterior bladder neck, which is incised (Figure 13.7). The posterior bladder neck is gradually dissected away from the prostate. The anterior layer of the Denonvillier's fascia, covering the vasa and the seminal vesicles is now exposed (Figure 13.8). This layer is incised precisely, exposing the vas and the seminal vesicles. The left-side assistant provides upward traction to the posterior base of the prostate to facilitate dissection of the vas and seminal vesicles (Figure 13.9). First, the vasa are skeletonized and transected, then held upward by the left assistant, providing further traction for dissection of the seminal vesicles. Care is taken in this location to avoid excess use of electocautery to avoid inadvertent damage to the neurovascular bundles. Both the vasa and seminal vesicles are then grasped and the posterior prostate is retracted upwards, allowing exposure of posterior layer of Denonvilliers fascia. An

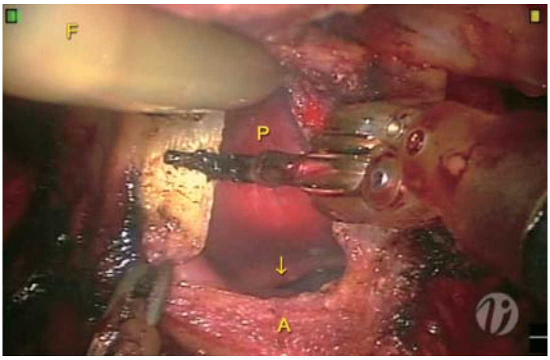

Figure 13.7. Exposure of the posterior bladder neck. Abbreviations: F, Foley catheter retracted by assistant; P, prostatic urethra; A, transected anterior bladder neck; ↓, left ureteric orifice.

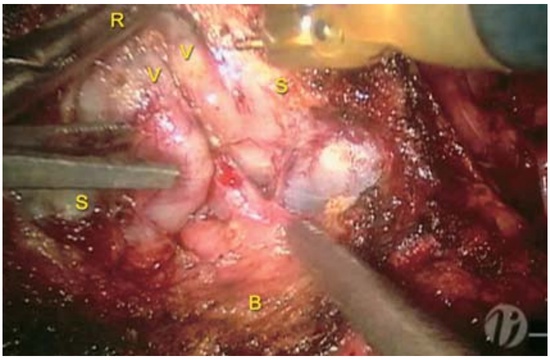

Figure 13.9. Exposure of the vas deferens and the seminal vesicles. Abbreviations: V, vas deferens; S, seminal vesicle; B, posterior bladder neck; R, left assistant's retractor lifting the prostate.

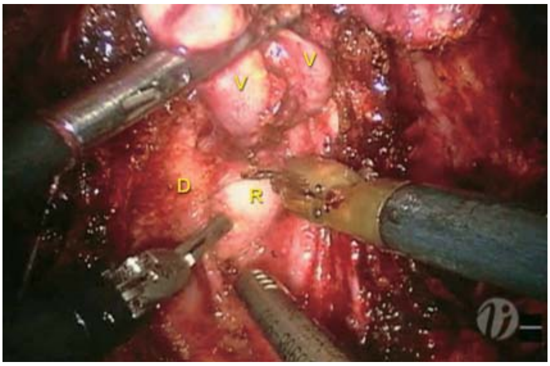

FIGURE 13.10. Incision in the posterior layer of the Denonvillier's fascia. Abbreviations: V, vas deferens; D, posterior layer of the Denonvillier's fascia; R, perirectal fat.

incision is made in this fascia and a plane is developed between the posterior layer of Denonvillier's fascia and perirectal fat. This is a avscualar plane and can be created easily by using the back of the monopolar hook without using electrocautery (Figure 13.10). The dissection is carried down to the apex of the prostate. The remaining attachments between the bladder and the prostate are divided, to expose the lateral pedicles of the prostate.

The base of the seminal vesicle is retracted superomedially by the assistant on the opposite side and the prostatic pedicle is delineated and divided. This pedicles lie anterior to the pelvic plexus and neurovascular bundle and includes only prostatic blood supply (Figure 13.11). The pedicles are controlled by either clipping or individually coagulating the vessels by bipolar cauterization.

FIGURE 13.11. Control of the left prostatic pedicle. Abbreviations: P, prostate; B, bladder; L, left prostatic pedicle.

13.2.4. Conventional Nerve Preservation

13.2.4.1. Objective

The conventional nerve preservation in the Vattikuti Institute Prostatectomy (VIP) procedure is based on the principle laid by Walsh. The posterolateral neurovascular bundles are sharply dissected off the prostate, leaving tracks like neurovascular bundles in the prostatic fossa (Figure 13.12)

13.2.4.2. Procedure

14.2.4.2.1. Robotic Instrument Change

- Right arm: Articulated robotic scissors

Articulated robotic scissors are used to incise the prostatic fascia anterior and parallel to the neurovascular bundles. The neurovascular tissue is then dissected off the prostate posterolaterally. The assistants retract the prostate in the direction of the contralateral shoulder of the patient to provide exposure. After the correct plane is entered, most dissection occurs in a relatively avascular plane (Figure 13.13). The dissection is then carried distally beyond the prostatic apex to expose the urethra posterolaterally.

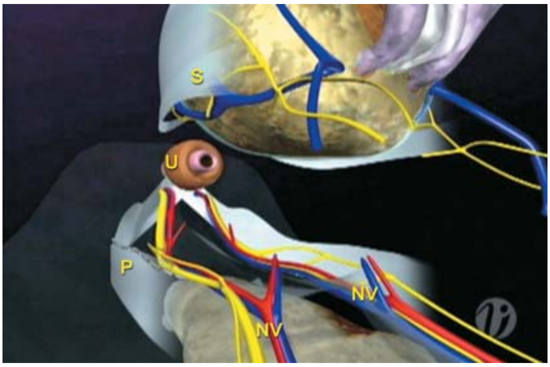

FIGURE 13.12. Schematics of the conventional nerve sparing. Abbreviations: U, urethral stump; P, prostatic fascia; NV, neurovascular bundle; S, radical prostatectomy specimen.

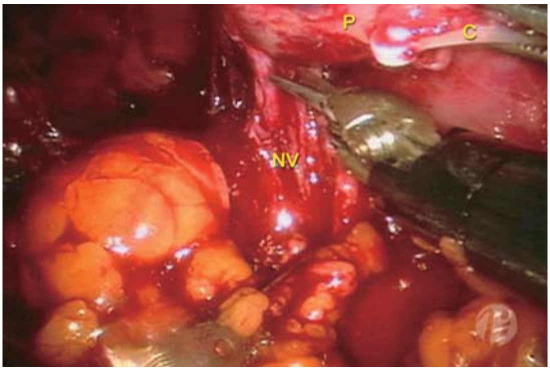

Figure 13.13. Left conventional nerve sparing. Abbreviations: C, Weck clip on the prostatic end of the left prostatic pedicle; P, prostate; NV, left neurovascular bundle.

13.2.5. The Veil of Aphrodite

13.2.5.1. *Objective*

In the veil of Aphrodite procedure, after the blood vessels of prostatic pedicles are controlled and cut, the lateral periprostatic fascia with all nerves and blood vessels is separated from prostate by sharp scissor dissection. The neurovascular complex supported by lateral periprostatic fascia stays with the patient (Figure 13.14).

13.2.5.2. *Procedure*

A plane between the prostatic capsule and the inner periprostatic fascial layer is developed at its cranial extent. The assistants provide superomedial prostate retraction and lateral retraction on the tissues adjacent to the neurovascular bundle. This allows the surgeon to enter a plane between the prostatic fascia and the prostate. This plane is deep to the venous sinuses of santorini's plexus (Figure 13.15).

Careful sharp and blunt dissection of the neurovascular bundle and contiguous lateral periprostatic fascia is performed until the entire periprostatic fascia up to and including the ipsilateral pubourethral aspect of puboprostatic ligament is mobilized in continuity off the lateral aspect of the prostatic apex. This plane is mostly avascular except anteriorly, where the fascia is fused with the puboprostatic ligament, capsule, and venous plexus. When performed properly, an intact veil of the periprostatic tissue hangs from the pubourethral ligament (Figure 13.16).

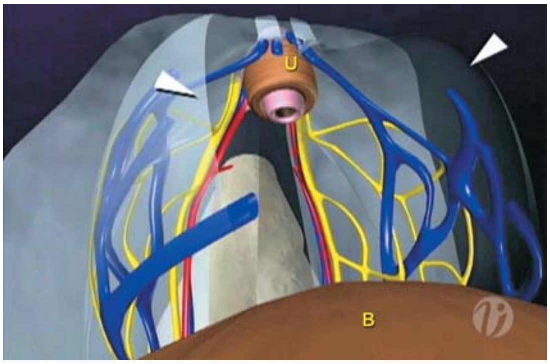

Figure 13.14. Schematics of the veil of Aphrodite. Abbreviations: U, urethral stump; arrowheads, Veil; B, bladder.

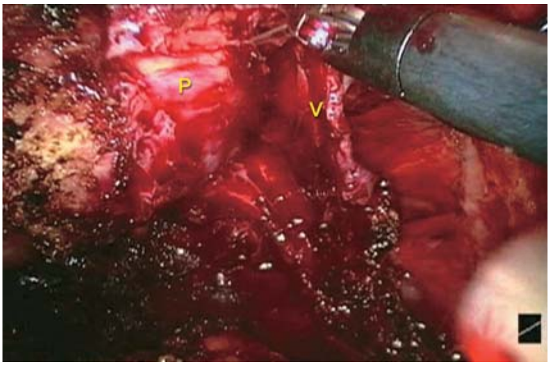

Figure 13.15. Plane of dissection for the veil of Aphrodite on right side. Abbreviations: P, prostate; V, right-sided veil.

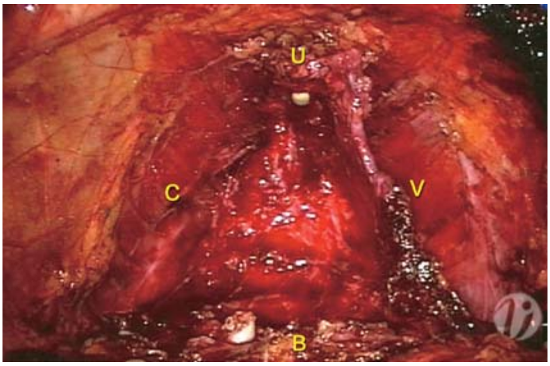

Figure 13.16. Completed veil of Aphrodite on right side and conventional nerve sparing on left side. Abbreviations: C, conventional nerve sparing; V, veil of Aphrodite; U, urethral stump; B, bladder.

We perform the veil of Aphrodite in localized prostate cancer patients with no palpable nodule and low-grade low-volume cancer.

13.2.6. New Modifications

13.2.6.1. Objective

To further refine the nerve sparing, recently we have added a few modifications to our procedure. We do not incise the levator fascia. In select cases with low-volume and low-grade disease, after the vesicprostatic disconnection we cut through the vasa and the seminal vesicles, sparing the distal part of the seminal vesicles. The rest of the dissection is similar to the veil of Aphrodite dissection. We believe that the lack of the dissection lateral to the lateral periprostatic fascia results in less handling of the nerve fibers; the resulting veil tissue is thicker and is better supported on the pelvic side wall.

13.2.6.2. Procedure

13.2.6.2.1. Robotic Instrument Change

- Right arm: Monopolar Hook Cautery (90 W)
- Left arm: Bipolar Forceps (25 W)
- Telescope: 30° directed upwards

In performing the modified veil operation after developing the extraperitoneal space using a 30° upward-facing scope, the telescope is switched to 30° downward facing for bladder neck dissection. The step of exposuring the prostatic apex and controlling the dorsal venous complex is omitted.

13.2.6.2.1. Robotic Instrument Change

- Telescope: 30° directed downwards

The bladder neck is then transected. The anterior Denonvillier's layer is opened to expose the vasa and seminal vesicles.

13.2.6.2.2. Robotic Instrument Change

- Right arm: Articulated robotic scissors

The vasa and seminal vesicles are cut. Their stumps are used by the assistants to retract the prostate in the course of the further dissection. The margins of both side seminal vesicles are biopsied and sent for frozen section analysis.

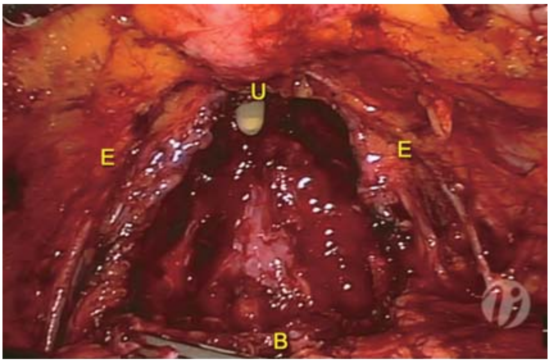

Figure 13.17. Completed bilateral veils with endopelvic fascia preservation. Abbreviations: E, endopelvic fascia with the veil; U, urethral stump; B, bladder.

The plane of dissection is similar to the veil operation. The venous sinuses may bleed due to lack of dorsal venous stitch at this stage. The bleeding is controlled by temporarily elevating the pneumo to 20 mm Hg and a tamponade by the assistants' instruments.

13.2.6.2.3. Robotic Instrument Change

- Right arm: Robotic Needle Driver
- Left arm: Robotic Needle Driver

Once the lateral peri prostatic fascia is dissected off the prostate from all sides, the dorsal vein may be then controlled by overrunning suture with 20 Vicryl on RB 1 needle.

The completed veil with this modification is thicker and is better supported by the surrounding tissue (Figure 13.17).

13.2.7. Incision of Dorsal Venous Complex and Urethra

13.2.7.1. Robotic Instrument Change

- Right arm: Articulated robotic scissors
- Left arm: Bipolar Forceps (25 W)
- Telescope: 0°

Using robotic scissors, the puboprostatic ligament is incised where it inserted into the apical prostatic notch. A plane between the urethra and the dorsal venous complex is gently developed to expose the anterior urethral wall. To minimize the possibility of a positive apical margin, the

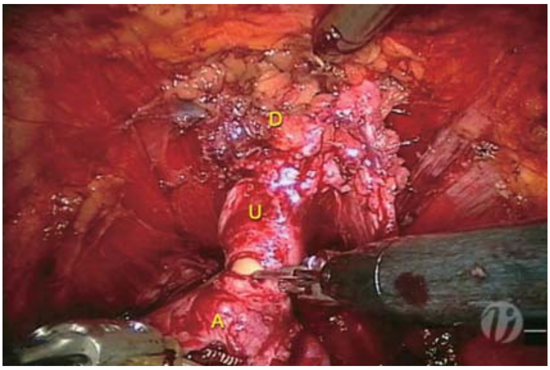

Figure 13.18. Transection of the urethra. Abbreviations: D, dorsal venous complex; U, urethra; A, prostatic apex.

anterior wall of the urethra is transected with the scissors a few millimeters distal to the apex of the prostate (Figure 13.18). The freed specimen is then placed in an Endocatch$^{\text{TM}}$ bag (US Surgical, Norwalk, CT). The prostate is removed later, following the completion of the anastomosis.

13.2.8. Lymph Node Dissection

The tissue overlying the external iliac vein is incised and lymph nodal package is pushed medially. The dissection starts at the lymph node of Cloquet at the femoral canal and continues toward the bifurcation of iliac vessels. The obturator nerve lies on the floor of this dissection and is carefully preserved (Figure 13.19). The magnification allows us to identify the vascular and lymphatic branches, including occasional accessory obturator vessels, which are carefully controlled by bipolar forceps or small clips. The lymph node package is removed through the 12-mm port and sent for permanent section. The prostatic and pelvic lymph nodal beds are inspected for any bleeding at pneumo pressures of 0 to 4 mm Hg. Any active bleeding is controlled by fine bipolar coagulation. The rest of the procedure is then completed at 15 mm Hg pneumo pressure.

13.2.9. Urethrovesical Anastomosis

13.2.9.1. Robotic Instrument Change

- Right arm: Robotic Needle Driver
- Left arm: Robotic Needle Driver

An MVAC suture is used for the vesicourethral anastomosis. The suture is prepared by tying two 3-0 monocryl sutures on a RB 1 needle, 7 inches in length, back to back. One suture is dyed and another is undyed. The suture is now a double-armed suture with a pladget of knots (Figure 13.20).

A 0° lens and a “no scaling: setting is used for this step of the operation. The suture is started with violet-dyed monocryl arm on the posterior bladder wall at the 4 o’clock position outside-in. The urethral bite is made inside out at the corresponding site. After three such bites, which cover a major portion of the posterior aspect of anastomosis, the bladder is brought down by tightening

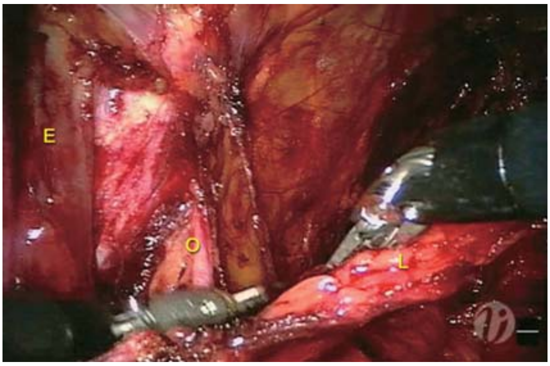

Figure 13.19. Left-sided pelvic lymphadenectomy. Abbreviations: E, external iliac vein; O, obturator nerve; L, lymphnode package.

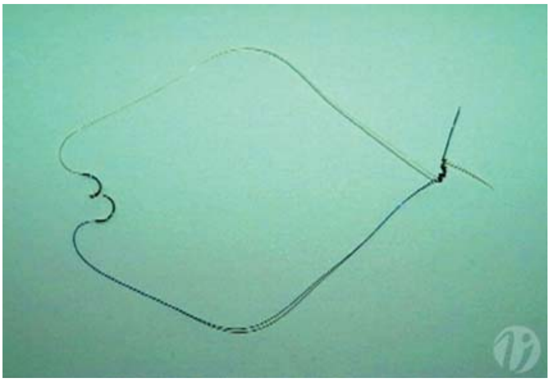

Figure 13.20. MVAC suture.

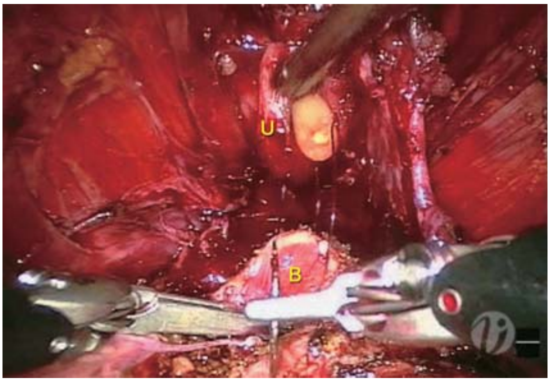

Figure 13.21. Anastomosis, sutures through the posterior wall. Abbreviations: U, urethral stump; B, posterior bladder wall.

the suture (Figure 13.21). Tightening the suture this way reduces the risk of sutures cutting through the urethral stump. A Connel stitch is then taken at the bladder, thereby changing the direction of passage of the needle from outside-in bladder to inside-out and inside-out at the urethra to outside-in. The suture is run clockwise up to 11 o'clock position, and at this point the suture may be locked and the suture then held by left assistant under gentle traction. The undyed arm is then run counterclockwise from 4 o'clock to 11 o'clock. During the placement of anastomotic sutures, the left assistant moves the tip of urethral Foley catheter out of the urethral stump to prevent suturing the back wall of urethra. The both arms of MVAC suture are tied to each other to complete the anastomosis.

A new 20 Fr Foley catheter is introduced and its balloon is inflated to 20 to 30 cc. The bladder is filled with 250 cc saline to test the integrity of the anastomosis.

13.2.10. Retrieval of Specimen and Completion of Surgery

A JP drain is placed through the left 5-mm port. The specimen within the Endocatch™ (Ethicon Endo Surgery, Cincinnati, OH) bag is removed after enlarging the umbilical port incision as required. The incision is closed with two interrupted suture of 0 Ethibond. The skin is closed by 4-0 Vicryl on PS2 needle using subcuticular sutures.

13.3. Evolving Role of Robotic Prostatectomy in Urology Practice

Radical retropubic prostatectomy has evolved over the last three decades to a precise, sophisticated procedure with minimal mortality and excellent surgical outcomes. To match this operation by minimally invasive means, minimal morbidity, and excellent functional and oncologic outcomes is an arduous task.

We have reported our experience with 1100 cases with excellent operative results,[9] lower complication rate,[10] and excellent functional results.[11] Encouraged by this and others similar experiences,[12,13] more centers are offering robotic prostatectomy for treatment of localized prostate cancer.

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14

Clinical Pearls: The Approach to the Management of Difficult Anatomy and Common Operative and Postoperative Problems

Vipul R. Patel

The task of learning robotic prostatectomy can be quite challenging for both novice and experienced open or laparoscopic surgeons alike. Therefore, prior to the first procedure, much training and planning is required as the entire surgical team prepares for the upcoming challenge. The learning curve to achieve basic competency has been estimated to be between 20 to 25 cases.[1,2] However, these initial patients are often selected as “ideal candidates” so that the surgical team can ease into the experience. After such cases are performed, the reality of the procedure sets in as one begins to entertain the idea of operating on those with more challenging anatomy.

After performing over 1200 cases, it is our opinion that no single learning curve exists and that there is a continual process of education and refinement. As one wave of the learning curve subsides, the next promises new challenges and innovation in technique. It is our belief that after the initial learning curve one naturally transitions to more challenging cases, often leading to longer surgical times and increased difficulty during surgery. This stepladder approach allows the surgeon to continually develop his/her skills to deal with even the most challenging patients. The ultimate goal is refinement in surgical technique, translated into improved surgical outcomes. In this chapter, we will discuss our approach to various challenges found during robotic prostatectomy and provide advice based upon our experience. The enclosed video and glossary of pictures provides a representation of our technique.

14.1. The Obese Patient

Patients that are of an abnormal body habitus can provide a technical challenge for any type of surgical approach: open, laparoscopic, or robotic. Abnormal body configurations often require the entire operative team, including anesthesia, nursing, and surgical staff, to deviate from their normal routine. This is particularly true for obese [body mass index (BMI) > 30] and morbidly obese patients (BMI > 40), as they often have a large girth and breadth. The increased amount of internal and external body fat, along with their medical co-morbidities, often provides a challenge with anesthesia, positioning, and the surgical approach. However, understanding and adapting to the intricacies presented by these patients, in addition to the nuances of robotic surgery, will allow the surgical team to optimize the chances of success.

In preparation for robotic prostatectomy, patients are placed supine, in low lithotomy with a moderate Trendelenburg position. It is of extreme importance that these patients be positioned properly, with adequate padding on the extremities, and stabilized to prevent unwanted movement during surgery. We recommend that the patient be placed centered on the table in low lithotomy with all pressure points padded on a desufflated bean bag that is strapped to the table. The desufflated bean bag will cradle the patient and prevent movement while the patient is in the Trendelenburg position. The specific positioning with illustrations is discussed in Chapter 10.

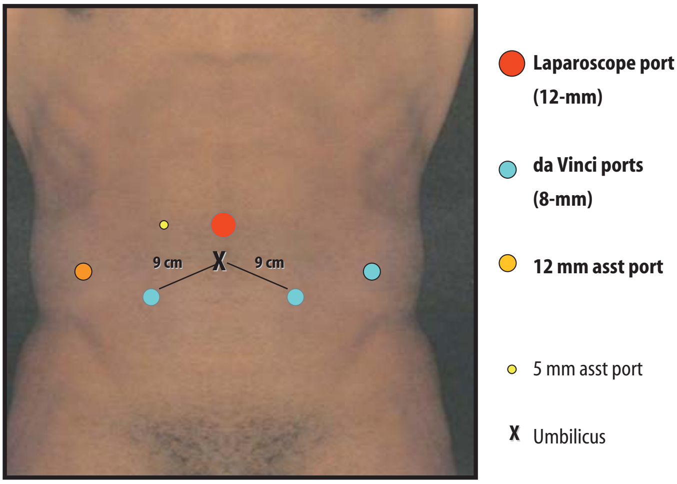

Figure 14.1. Trocar placement.

Once the patient is positioned, the next step is in determining optimal trocar selection and placement. For obese patients, we recommend using the extra long da Vinci® robotic system (Intuitive Surgical Inc., Sunnyvale, CA) trocars and accessory instrumentation. This will allow the center point of the trocars to stay at the fascia level, facilitating optimal movement; in addition it will prevent the tips of the trocars from slipping out of the abdominal wall should there be an inadvertent drop in insufflation pressure.

Even in obese patients we have tended to keep our trocar placement constant to optimize our movement of the robotic instruments and that of the assistant. Our standard trocar placement is shown in Figure 14.1. Of note, our trocar placement has stayed constant over the last 1000 cases. The assistant ports are placed well back to allow maximum maneuverability without obstruction by the robot. We do not measure the pubic bone to umbilicus length, as this is not the main issue in these patients; it is more the challenging angles created by their body habitus. Many obese patients have an abdominal wall that is quite lax and inflates like a dome moving the trocars further up and out (see Figure 14.2).[3] In addition, the trocars are elevated well above the level of the pubic bone, often providing a challenging angle for the robotic instruments as they try to tackle the apical area of the prostate. In this situation instruments are often obstructed by the pubic bones. This will often require readjusting of the angles of the robotic arms by tucking them in lower on the abdominal wall. Even with these adjustments, it is possible that during the operation instruments may have difficulty reaching; in this scenario the trocars can be advanced further by pressing the joint release and inserting the trocar further into the abdomen under direct vision. It should be noted that this will often offset the center point of the trocar and should only be performed under necessitating circumstances. The newer version of the robot, the da

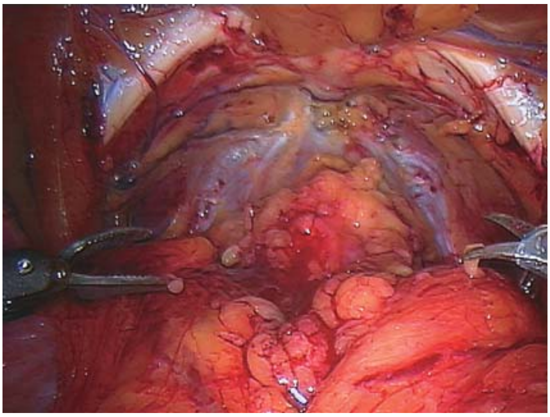

Figure 14.2. Retropubic view of the prostate.

Vinci® S system, is equipped with instruments that have a two-inch longer reach and therefore adjustment of trocar placement has not been necessary.

Another essential point that cannot be over emphasized is the importance of correct technique during trocar insertion in patients with thick abdominal walls secondary to fatty tissue. Due to the large distance between the skin and the fascia in these patients, an incorrect angulation of the trocar during insertion through the skin can be exaggerated significantly by the time it pierces the fascia. Optimally, the trocar should be inserted into the abdomen, completely perpendicular to the abdominal wall and fascia. In obese patients, a tangential insertion will lead to the trocar entering the fascia at a location much distal to that of the entry through the skin. This will alter the center point of the trocar and require it to pivot at two widely placed points of resistance at the skin and the fascia, potentially interfering with optimal instrument movement.

Once the operation has begun, obese patients often provide the additional challenge of increased intraabdominal fat obscuring the vision of the surgical field. It is essential that the patient has been placed in Trendelenburg position and that adequate insufflation pressures be maintained. In addition, adequate retraction of the intraabdominal contents will be necessary. We have found it beneficial to use a fourth robotic arm to hold back the fat and provide exposure. Another option is to use the assistant for this purpose. In obese patients, the anastomosis can be a challenge as the angles of the instrumentation and the working space is less than optimal. The key is to maintain adequate retraction and exposure while optimally using the wristed instrumentations to compensate for the lack of space and agility.

14.2. Postinguinal Hernia Repair

Radical prostatectomy, either open or laparoscopic, performed after the prior repair of an inguinal hernia, especially with the placement of mesh products, can be challenging for the surgeon. The key issue is distortion of the planes in the retropubic space secondary to scarring from the prior dissection or placement of mesh. This problem can be similar after open or laparoscopic inguinal hernia repair surgery; however, the most difficult dissection is thought to be after a laparoscopic preperitoneal hernia repair as the exact space that we enter during the robotic prostatectomy is violated.

While hernia repair does distort the surgical anatomy, we have not found it to significantly deviate the surgical approach. The key has been identification of the surgical landmarks and precise dissection below the level of the hernia repair. Via the transperitoneal approach it is usually quite simple to recognize that a hernia repair has been performed as the mesh, sutures, or tacks are usually quite prominent laterally on the pubic bone. Our recommended approach is to first visualize the normal anatomy, the urachus, median umbilical ligaments, vasa, and, if possible, the pubic bone. The initial incision is best made in the midline above the bladder and then carried laterally. If one has difficulty visualizing the boundaries of the bladder, it can be filled externally via the urinary catheter with 200 cc of fluid to provide a more distinct anatomy. It is important to enter the retropubic space in the midline and localize the symphysis pubis early. The optimal approach to avoid the majority of the scar tissue and the mesh. This is accomplished by keeping the plane of dissection inferior to the pubic rami (see Figure 14.3). Once the symphysis has been identified the inferior portion of the rami can be followed laterally to the boundary of

Figure 14.3. Obese patient with rotund abdomen.

the vasa. This will often provide a plane below the area of repair and fibrosis.

14.3. The Bladder Neck Dissection

Dealing with nuances of the bladder neck is probably the most challenging aspect of the robotic prostatectomy. The unique variability of the anatomy at the bladder neck can pose quite a formidable task to even the most adept surgeon. The key is recognizing the anatomical landmarks and providing a precise dissection in a clear surgical field.

The anterior bladder neck can be recognized in a variety of ways. One option is to observe the level of descent of the urethral catheter with a gentle tug. However, this maneuver can be compromised if there is a median lobe or the presence of a prior transurethal resection of the prostate (TURP). The optimal method is by visualizing the borders of the prostate laterally after the periprostatic fat has been cleared off. The cessation of the bladder fat as it approaches the prostate is usually the most reliable indicator of the boundary between bladder and prostate. Once it is located it should be dissected precisely to prevent inadvertent entry into the prostate. Our recommendation is to use the bipolar grasper and monopolar scissors to dissect on either side of the midline following the flowing lateral contours of the prostate. If difficulty is found locating the planes of dissection, one should follow the bladder fibers down the midline as this will lead to entry into the anterior bladder at a safe location. Once the bladder has been entered the urinary catheter can be identified and retracted superiorly to expose the posterior bladder neck.

The posterior bladder neck is best approached by incising the bladder neck full thickness and then dissecting directly downwards. The bipolar grasper can be used to manipulate the posterior bladder neck and help identify the contour of the posterior plane. The dissection should be limited to the midline unless absolutely necessary, as lateral migration of the dissection will often lead to opening of the peripheral venous sinuses. If during the dissection one sees vertically oriented white fiber then these are of bladder origin. Incising these fibers horizontally will lead you into the correct plane to locate the seminal vesicles under the prostate. The dissection is illustrated in Appendix A.

It is important to continually visualize the anatomy and progression of the dissection by using the advantages of magnification and three-dimensional (3D) vision. The key is to avoid dissecting forward into the prostate as this may compromise oncologic outcomes and obscure the surgical planes. A not uncommon scenario during the initial experience is difficulty locating the true anatomy of the posterior prostate or locating the seminal vesicles. If the seminal vesicles cannot be located then, one option is to locate the lateral border of the prostate and then work backwards to the pedicle. Elevation of the lateral border in the same manner, as if one is attempting to provide an early release of the neurovascular bundle, will allow one to approach the bladder neck from another angle. The key is to work backwards along the lateral border of the prostate to the pedicle, which is subsequently clipped and divided. This should allow sufficient medial rotation of the prostate to identify the rectum, Denonvillier’s fascia, and the seminal vesicles.

14.4. Posttransurethral Resection of the Prostate

Many patients presenting with a diagnosis of prostate cancer have had a prior TURP or were diagnosed in such a manner. While the grade and stage of the cancer in these patients is variable, their optimal treatment is still often prostatectomy. The variation in the anatomy caused by the TURP can provide a challenging surgical scenario for even the most experienced of surgeons.

Our approach to these patients has been to wait a minimum of eight weeks after TURP to allow for healing and a decrease in the inflammation prior to the prostatectomy. We also advocate performing cystoscopy in these patients at about six weeks post-TURP to make sure that sufficient healing of the tissue has occurred. The most common challenge in these patients is during the bladder neck dissection. The anatomy of the true bladder neck is distorted by the TURP, often making it difficult to locate and dissect. It should be cautioned that using traction on the urinary catheter balloon to detect the location of the bladder neck in these patients can be misleading. A generous TURP can lead to a large cavity in the prostate into which the catheter balloon can lodge, distorting the perception of the bladder neck to a more distal location. The most optimal method to locate the bladder neck is by judging its location using visual clues. The 3D visualization provided by the da Vinci® system will often allow clean visualization of the contour and boundaries of the prostate. In addition, the cessation of the fat coming from the bladder at the level of the prostate is the most obvious clue. The bladder fat can be seen to stop at the level of the borders of the prostate and the bladder neck. In these specific patients, it is often best to approach the bladder neck dissection in the midline, to quickly enter the bladder, to elevate the prostate using the urinary catheter, and to survey the anatomy from the inside.

The posterior bladder neck dissection often provides the most ominous challenge in post-TURP patients. There are two common scenarios. If the patient has had the TURP many years prior, then there can be regrowth of tissue that obscures true anatomy of the posterior bladder neck. The key in these patients is to identify the tissue regrowth early in the dissection so that it can be accommodated. In other instances, the area has healed and re-urothelialized, making it difficult to distinguish the boundary between bladder and prostate. We recommend that in post-TURP patients, the ureteral orfi be visualized as they are often very close to the site of the posterior dissection. One ampule of indigo carmine given about 15 min prior to beginning the bladder neck dissection with a small bolus of fluid is often sufficient to visualize them and evaluate their integrity. It is essential to visualize a blue efflux of urine at some point during the procedure, as it will confirm both their location and integrity.

The posterior bladder neck should be approached with cautious optimism. Even if the efflux of urine has not been visualized, as long as the location of the orfi have been located then the bladder neck dissection can begin. The prior TURP will often decimate the true surgical planes especially at the level of the seminal vesicles, creating a challenging scenario. The key to the posterior bladder dissection in these patients is to dissect carefully and observe the anatomy of the prostatovesical junction during dissection. We perform this dissection by first locating the ureters and the true bladder neck. The bladder neck is then incised full thickness and the dissection is carried inferiorly, making sure not to advance forward into the prostate tissue or to advance too far towards the bladder. Usually the best practice is straight downwards to locate the seminal vesicles.

If, after a prolonged period (approximately 30 min), no efflux is visualized and the bladder neck dissection has been performed, then the integrity of the orfi should be tested. This is to ensure that no injury to the ureters has occurred. Urine output can be encouraged using small fluid boluses with diuretics if necessary. A 500-cc bolus of normal saline with 10 mg of lasix is often sufficient. If this is not successful, then small pediatric-sized (5 Fr) feeding tubes can be passed via the trocars and advanced up the ureters bilaterally using the robotic instruments. If a ureteral injury is identified, the best method of treatment is usually reimplantation after excision of the injured and devascularized segment.

We also recommend reconstructing a wide open bladder neck in order to internalize the ureters away from the anastomotic sutures. This will also simplify the performance of the vesicourethral anastomosis. We have found that the simplest and most effective way to reconstruct the bladder neck has been to use 3-0 monocryl figure of eight sutures at the three and nine o'clock positions rather than the traditional tennis racket closure.

14.5. Median Lobe

The protrusion of a median lobe of prostatic tissue into the bladder neck can provide a surgical challenge during the laparoscopic approach to prostatectomy. Because the laparoscopic approach is in an antegrade manner, it is often difficult to distinguish the true plane between the bladder neck and the prostate. The presence of a median lobe further complicates this matter.

The first step in dealing with a median lobe is to diagnose its presence. This can be done preoperatively with cystoscopy or ultrasound, otherwise intraoperatively. We recommend a preoperative diagnostic workup on the first 25 patients to look for anatomical variations such as this. If the diagnosis is not made preoperatively, then there are clues during the surgery that can help. Prior to the bladder neck dissection, a gentle tug on the urinary catheter will show contralateral deviation of the balloon away from the side of a unilateral median lobe. In patients with a circumferential or midline median lobe, the urinary catheter will be seen not to descend to the level of the true visualized bladder neck.

The dissection of the median lobe should be performed in a precise and methodical manner to minimize adverse outcomes. Our recommended approach to the anterior lobe is to follow the tissue planes around the curvature of the prostate. The dissection begins in the midline as it is often the optimal place to locate the bulk of the median lobe. If one enters the correct plane, then the lobe literally guides you around its circumference to the level of the bladder neck. As the dissection proceeds it should be gradually carried laterally to avoid ending up in a deep hole. Once the anterior portion of the lobe has been dissected free, the true bladder neck should be localized in the midline for a central lobe or off to the side for a unilateral lobe. The bladder neck should be opened and the urinary catheter grasped to elevate the prostate anteriorly. Once the prostate is elevated anteriorly, many of the venous sinuses become compressed, improving the visualization during dissection.

For a wide open bladder neck, the posterior median lobe should be easily visualized (Figure 14.4). The clue to whether a lobe exists or not is the presence or absence of a bladder drop off. If, after opening the bladder, the posterior bladder neck can be seen dropping downwards into the body of the bladder then no lobe is present. If instead the bladder is seen continuing straight back without a drop off, then one is likely to be present. The median lobe can be lifted out of the bladder neck and retracted upwards to locate its junction with the bladder. If the lobe is quite large it may require opening the bladder anteriorly to track it back posteriorly to provide adequate exposure.

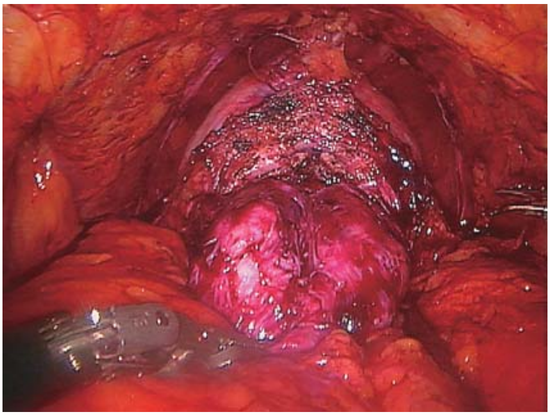

Figure 14.4. Exposure of posterior bladder neck and median lobe.

The lobe can be elevated outside of the bladder using the fourth robotic arm for retraction (Figure 14.5). This provides exposure to the inferior aspect of the median lobe as it meets the true bladder. The bladder is scored directly inferior to the base of the median lobe and incised full thickness to enter the correct plane. Once the lobe has been retracted superiorly, the ureteral orfi should be visualized as they can often lie close to the boarders of a large lobe. The maneuvers described above can be used to identify them. The first step in dissecting the posterior portion of the lobe is to score its boarder with the

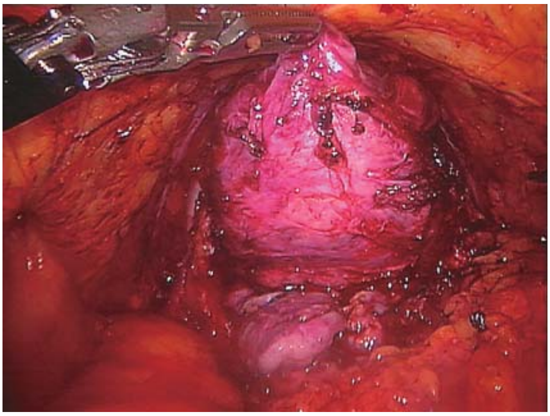

Figure 14.5. Using the fourth robotic arm to elevate the median lobe of the prostate.

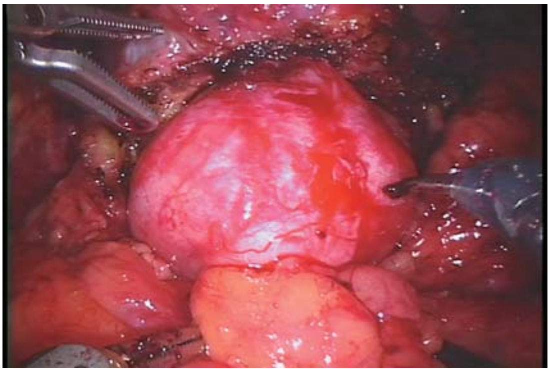

Figure 14.6. Complete dissection of the prostate and median lobe.

bladder circumferentially. We prefer to begin the dissection at the most lateral corners of the bladder, working our way medially. This allows optimal visualization of the corners. The bladder neck should then be divided full thickness. The posterior bladder dissection in these patients often varies from that of patients without a lobe and, therefore, some subtle changes in technique need to be made. The protrusion of the lobe alters the anatomy of the posterior bladder neck, pushing it into the bladder. The initial dissection should progress forward under the median lobe and then once the median lobe has been passed the direction is downward along the contour of the bladder. This is best performed with clear visualization of the surgical field and observation of the bladder fibers. With larger prostates this dissection can go quite deep; however, as long as the anatomy is followed the dissection should proceed without complication (Figure 14.6).

14.6. The Large Prostate

Prostates that are larger than 100 g can also pose a surgical dilemma. These larger sizes pose many anatomical challenges as they often occupy a large portion of the pelvis, making exposure and rotation of the prostate difficult during dissection. In addition, the larger prostates often have a generous blood supply, making vascular control an increased challenge. However, if approached correctly, these cases can be performed with relative efficiency and low complication rate.

We recommend preoperative evaluation of all candidates during the first 25 cases of the learning curve and avoidance of such large prostates. The key to dissection of an enlarged prostate is early identification and certain technical maneuvers to optimize the outcomes. Opening the endopelvic fascia and early control of the dorsal vein will allow clear identification of the borders and ligation of some of the vascular flow to the prostate. The bladder neck is once again potentially the most challenging aspect of the dissection, as the large volume of the prostate requires a technically precise dissection in the correct plane. The key is providing a broad enough exposure to allow an adequate dissection without ending up in a deep hole. In some respects, the contour of the larger prostates is easier to follow as the curvatures and boundaries can be more obvious. The key is to stay in the correct surgical plane between the two and to minimize the bleeding. Once the anterior bladder has been entered, the urinary catheter should be retracted to elevate the prostate superiorly, exposing the posterior bladder neck.

The posterior dissection is often quite challenging in these large prostates, as often one has to dissect deeply in the posterior plane to reach the seminal vesicles. The key element in this dissection is wide exposure and a relatively bloodless field. The dissection should be carried straight down. The same rules discussed in the section for the bladder neck dissection should be followed.

14.7. The Vesicourethral Anastomosis

During the initial experience with robotic prostatectomy, it can be challenging to perform the vesicourethral anastomosis. One of the technical challenges can be bringing the posterior bladder neck down to the urethra. This difficulty can be obviated with a few simple steps. During the initial dissection, the peritoneum should have been mobilized lateral to the median umbilical ligaments and down to the intersection of the vasa bilaterally, providing adequate release of the bladder. The key to getting the bladder down to the urethra is the optimal placement of the sutures and correct manipulation of the suture while sliding the bladder down to the urethra. We recommend taking generous bites (approximately 0.5 cm) of both the bladder and urethral tissue. The anastomosis should be begun by taking an outside in stitch on the bladder at approximately the five o'clock position and then inside out at the same position on the urethra. Three passes through the bladder and two through the urethra are made prior to attempting to pull the bladder down. The mechanics of manipulating the stitch during the descent of the bladder are important to getting a close, tension-free approximation. The suture should be pulled directly vertically in a hand over fist manner using the two needle drivers. This provides the optimal angle and tension for the suture, allowing the bladder to slide down with the least difficulty. If there is still the presence of some tension or separation of the anastomosis, we recommend cinching up the anastomosis and performing another pass through the bladder and urethra, then tightening up again. Another option is to use the fourth robotic arm to hold the anastomosis together while placing reinforcing sutures. This should relieve the problem. Many of these maneuvers are demonstrated in the video provided with this book.

If a situation is encountered that the two will not approximate, one option is to move the location of the bladder neck anteriorly as the anterior portion of the bladder is likely to roll forward more easily. This can be performed by opening the bladder neck anteriorly in the midline and then suturing closed the area of the true bladder neck. This will move the bladder neck to a more maneuverable position.

14.8. Immediately Increased Postoperative Drain Output

The placement of a surgical drain after robotic prostatectomy is essential, especially during the initial learning experience. The drain is placed at an inferior trocar site and is removed the next morning without consequence to the patient. While the risk of placing a drain is quite minimal, the benefits are potentially quite substantial. At our institution, we continue to use a surgical drain even after 1200 cases, as it provides an early clue to postoperative problems. Though rare, postoperative problems are best diagnosed and treated promptly, making the placement of a surgical drain a worthwhile and essential part of the operative procedure.

One of the most disturbing and perplexing immediate postoperative problems is the issue of the urinary leak. The placement of a surgical drain will often alert the surgeon to the presence of increased urinary extravasation immediately after surgery. A common scenario is where the patient, while in the recovery room, immediately begins to have increased fluid output from the drain. The two common causes are either hemorrhage or urinary leakage. The hemorrhage will be relatively easy to diagnose as it will be the prolonged leakage of frank blood associated with falling hemoglobin levels and possible hemodynamic instability. A more common scenario, especially early in the learning curve, is the drainage of initially serosanguinous and then clear fluid, representing urinary leakage. During the initial experience with robotic prostatectomy, the anastomosis may not be completely approximated and therefore it is not uncommon for the majority of the urine to be leaking out of the drain instead of the urinary catheter. Immediately after surgery this is most likely to be disruption or nonunion of the vesicourethral anastomosis.

There are some fundamental steps that can be used to negotiate these problems.

Step 1. Irrigate the urinary catheter to confirm placement inside of the bladder and to irrigate out any potentially obstructive clots.

Step 2. Place the Jackson Pratt drain (JP drain) on bulb suction and empty immediately once it is full. Failure to empty the drains promptly will lead to increased surgical discomfort for the patient in the lower abdomen. If greater than 50% of the urine is coming out via the surgical drain, then this is a process that will usually last many days and the ratios will slowly change in favor of complete drainage eventually via the urinary catheter. It is best to reassure the patient at this point.

Step 3. The prolonged drainage of fluid from the drain beyond the initial postoperative period

(24 h) should lead to certain essential diagnostic steps. First, the fluid should be tested for creatinine level to confirm it is of urinary origin. Next, a plain abdominal radiograph of the kidneys, ureter, and bladder (KUB) should be performed to insure that the drain has not been placed directly over the anastomotic site, as this will create a fistula. If the drain has been placed inadvertently over the site, it should be withdrawn a few inches away from the site.

Step 4. If the urinary leakage is prolonged beyond a few days, coverage with broad spectrum antibiotics must be considered. In addition, the possibility of a nonanastomotic site injury must be entertained, such as ureteral injury or vesical injury at a site away from the anastomosis. This can often be diagnosed with and intravenous pyelogram.

In the majority of situations, the leakage is from a nonunion at the anastomosis. Bladder drainage with the urinary catheter and prompt emptying of the drain will provide sufficient treatment. The patient should be reassured that while it will take a few day it will usually resolve spontaneously. A period of 4 to 7 days is not unusual for the trend to reverse completely; however, the above diagnostic maneuvers are recommended early.

14.9. Postoperative Urinary Retention and Nonunion of the Vesicourethral Anastomosis

After robotic prostatectomy, the urinary catheter is typically removed between 4 to 10 days after surgery. With increasing experience the trend is towards earlier removal. However, especially during the initial learning curve, it is not uncommon to have delayed healing of the anastomosis secondary to a nonwatertight anastomosis or delayed disruption of the sutures.

We recommend that a gravity cystogram be performed to confirm lack of extravasation from the anastomotic site prior to the removal of the urinary catheter. The cystogram can be performed routinely in the radiologic suite and evaluated by the radiologist for leakage. If no extravasation is present, a voiding trial should be performed by filling the bladder under gravity with approximately 200 cc of saline prior to removal of the urinary catheter, after which the patient is expected to void at least that amount to completion with a good urinary stream. Failure to empty completely or the presence of a poor urinary stream will indicate that the patient should void once more prior to leaving and have urinary emptying confirmed with a bladder scan.

Evidence of a postoperative urinary leak from the anastomosis represents lack of healing at the site. The extravasation may result in patient discomfort in the perineal area. The treatment is usually just prolonged urinary drainage with the catheter and reassurance of the patient. If the leakage is minor it may take only a few days to resolve; however, a large leak can take up to four weeks. A weekly cystogram will usually show gradual improvement as the extravasation begins to first decrease and then form a confined cavity that gradually decreases in size prior to complete union of the anastomosis. If hematuria becomes significant during this period, it is advisable to ask the patient to moderate activity and maintain a health urine output.

14.10. Conclusion

The development of expertise in robotic prostatectomy, while rewarding, is not without its challenges, frustrations, and complications. Anyone performing this procedure will have to undoubtedly deal with the scenarios that we have discussed above. The key to negotiating the challenges provided during the learning curve is judicious initial patient selection and then a graduated exposure to more challenging surgical cases.

With adequate training and good clinical judgment, the majority of surgeons should be able to adequately deal with even the most challenging of cases to obtain adequate patient outcomes. From our experience of over 1200 robotic prostatectomies, we can testify to the fact that the learning curve is indeed endless as one continually experiences new challenges and refines surgical technique to optimize patient outcomes. Robotic surgery is indeed an art and, therefore, each patient should be treated as a distinct and unique masterpiece.

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15A

The French Experience: A Comparison of the Perioperative Outcomes of Laparoscopic and Robot-Assisted Radical Prostatectomy at Montsouris

Justin D. Harmon, Francois Rozet, Xavier Cathelineau,
Eric Barret, and Guy Vallancien

The robotic-assisted laparoscopic prostatectomy (RALP) has gained rapid acceptance in the urological community due to its documented advantages over standard laparoscopy radical prostatectomy (LRP)[1,2] and open prostatectomy.[3–5] This advantage has been most appreciated with regards to the learning curve due to enhanced three-dimensional visualization and instruments that allow six degrees of freedom of motion.[6] These benefits to the surgeon must, however, translate to improved overall outcomes to justify the increased economic burden placed by the robot.[7–9] In this chapter, we will review the current literature for the peri-operative morbidities of RALP. Due to our extensive experience with pure LRP at Montsouris,[10,11] the minimally invasive standard to which the RALP must be compared, we will reference the current literature and our own series of both RALP and LRP to make the necessary comparisons for this developing technology.

15A.1. Robotic-Assisted Laparoscopic Prostatectomy

The current series at Montsouris consists of over 2200 laparoscopic prostatectomies, over 130 of which have been completed using the RALP technique.[10–12]

With regards to patient outcomes, the literature for these minimally invasive approaches is not fully mature. Table 15A.1 shows the most recent series of RALP.[6,12–15] For comparison, Table 15A.2 shows the most recent series of LRP.[11,16–25] The first series of LRP, described by Schuessler and colleagues, has been included in Table 15A.1 to demonstrate the technical progression.[25]

Similar to the single institution comparison data that are available for open surgery versus LRP,[21,26,27] RALP and LRP comparisons have been published.[1,2,28] The RALP and LRP comparison series are seen in Table 15A.3,[1,2,28] along with outcomes from the first 2208 LRPs performed at Montsouris compared to the first 105 RALPs performed. This offers the unique perspective of comparing the two techniques in the hands of a single surgeon or operative team.

15A.1.1. Operative Time

The operative times for the RALP and LRP series are given in Tables 15A.1 and 15A.2. Operative times for RALP range from 141 to 250 min, with a mean time across series of 182 min. At Montsouris, a time of 180 min for the LRP group was compared to 155 min for the RALP group (Table 15A.3), and no statistically significant difference was observed. This finding is true for other single institution studies.[1,2,28] The average time across

TABLE 15A.1. Robotic-assisted laproscopic prostatectomy.

Series	*N*	Approach	Operating room time (min)	Estimated blood loss (cc)	Transfusion (%)	Conversion (%)	Complication (%)	Hospital stay (days)	Positive margin (%)	Continence (%)	Potency (%)
Patel et al.	200	Trans	141	75	0	0	1	1	10.5	98	n.r
Cathelineau et al.	105	Trans/ extra	155	500	6	2 to LRP	7	5.5	22	70	79
Menon et al.	250	Trans	160	153	0	n.r.	4	1.2	6	96	82 (<60 y)
Ahlering et al.	45	Trans	207	145	n.r.	n.r.	8.8	1.5	35.5	81	n.r.
Wolfram et al.	81	Trans	250	300	12	n.r.	n.r.	n.r.	22.2	n.r.	n.r.

Abbreviations: extra, extraperitoneal; n.r., not reported; trans, transperitoneal; LRP, laparoscopic robotic prostatectomy

TABLE 15A.2. Laparoscopic radical protatectomy.

Series	*N*	Approach	Operating room time (min)	Estimated blood loss (cc)	Transfusion (%)	Conversion (%)	Complication (%)	Hospital stay (days)	Positive margin (%)	Continence (%)	Potency (%)
Stolzenburg et al.	700	Extra	151	220	0.9	0	2 major, 9.7 minor	n.r.	10.8 pT2, 31.2 pT3	92	47.1 b/l sp.
Rozet et al.	599	Extra	173	380	1.2	0	2.3 major, 9.2 minor	6.3	17.7	84	64
Brown et al.	122	Trans	197	n.r.	3.27	1	11	2.1	24	87	55
	34	Extra	191	n.r.	0	5.8 to trans	12	1.6	21	75	25
Eden et al.	100	Trans	238.9*	310.5*	2	1	8	3.8*	16	56	61
	100	Extra	190.6*	201.5*	0	0	4	2.6*	16	80	82
Ruiz et al.	165	Trans	248.5*	678*	1.2	n.r.	9,1	6.7	23	n.r.	n.r.
	165	Extra	220*	803*	5.4	n.r.	6,1	6.3	29.7	n.r.	n.r.
Roumeguere et al.	85	Extra	288	400	n.r.	2.3	5 major, 24.6 minor	6	7.8 pT2	80.7	65
Rassweiler et al.	438	Trans	218 (last 219)	800 (last 219)	9.6	0.5	10	12	23.7	95.8	n.r.
Gregori et al.	80	Trans	218	376	53auto/6	0	23	4.5	31.25	n.r.	n.r.
Hara et al.	26	Trans	453	850	3.8	0	19	n.r.	n.r.	100	71
Turk et al.	125	Trans	265	185	2	0	34	7.5	26.4	92	59
Schuessler et al**	9	Trans	564	583	n.r.	0	33	7.3	11	66	50

Abbreviations: extra, estraperitoneal; n.r., not reported; trans, transperitoneal.

*$p < 0.05$.

**Reference series.

TABLE 15A.3. Single institution series.

Series	Approach	Year	*N*	Approach	Operating room time (min)	Estimated blood loss (cc)	Transfusion (%)	Conversion (%)	Complications (%)	Hospital stay (days)	Positive margin (%)
IMM	LRP	2005	2208	Trans/ Extra	180	360*	3*	0	7.3	4	15.8
	RALP		105	Trans/ Extra	155	500*	9.8*	2 to LRP	7	5.5	22
VIP	LRP	2002	40	Trans	258	391*	n.r.	2.5 to open	10	n.r.	25
	RALP		40	Trans	274	256*	n.r.	0	5	1	17.5
University of Rochester (NY)	LRP	2005	50	Extra	264	299*	0	2 to trans	4	2	14
	RALP		50	Extra	277	206*	0		8	2	12

Abbreviations: extra, extraperitoneal; IMM, XXX; n.r., not reported; trans, transperitoneal; VIP, Vattikuti Institute prostatectomy; LRP, laparoscopic robotic prostatectomy; RALP, robotic-assisted laparoscopic prostatectomy.

*$p < 0.05$.

series for LRP is 234 min, with a range of 151 min to 453 min. This is a dramatic reduction when compared to the time of 564 min observed with Schuessler and colleagues's original description.[25] At Montsouris, the operative time has also decreased from 200 min in the earlier series[29] to 173 in the most recent series of LRP.[11] It must be remembered, however, that these are well developed series from experienced centers, and that this difference may prove to be more significant in the community setting.

15A.1.2. Estimated Blood Loss

Estimated blood loss for the RALP averages 234 mL, with a range of 75 mL to 500 mL (Table 15A.1). Estimated blood loss for LRP ranges from 185 mL to 850 mL, with an average across series of 482 mL (Table 15A.2). At Montsouris, this statistic has not changed when comparing our earlier and later series.[11] Table 15A.3 shows each series having significantly different blood loss between approaches. Menon and colleagues and Joseph and colleagues each report less blood loss with the RALP (391 mL for LRP vs. 256 mL for RALP in Menon et al., and 299 mL for LRP vs. 206 mL for RALP in Joseph et al.).[1,2] At Montsouris, the contrary was found. Mean estimated blood loss for the LRP series was 360 mL while an estimated blood loss of 500 mL was observed in the RALP group ($p < 0.05$). The rate of transfusion differed significantly in our series from 3% in the LRP to 9.8% in the RALP group ($p < 0.05$). The other series did not report this observation.[1,2] In summary, differences in blood loss vary by institution, and although a trend toward less blood loss can be seen in the RALP series, definitive conclusions cannot be made at this time.

15A.1.3. Complications

The reporting and description of complications varies greatly between authors as no unified classification schema has been uniformly used. Table 15A.1 shows a range of 1% to 8.8% in the RALP series. Table 15A.2 shows a range of overall complication rates from 4% to 34% in the LRP series. Due to the large discrepancy between these series, important information is gained by looking at the single institution studies in Table 15A.3. At Montsouris, we observed a 7.3% complication rate with the LRP and a 7% rate with the RALP. The other authors in Table 15A.3 agree that no significant differences are seen between each approach.[1,2,28]

As institutional experience increases, conversion rates tend to decrease. Table 15A.3 shows that it is relatively rare to convert to open surgery (2.5% in the Menon et al. series of LRP), and that conversion from RALP to LRP (two patients in the Montsouris RALP series) and from extraperitoneal to transperitoneal laparoscopy (two patients in the Joseph et al. series) are more common based on surgeon experience and comfort level.[1,2,28] Overall, there is no difference in conversion when comparing LRP to RALP.

15A.1.4. Hospital Stay

Hospital stay is another factor that is difficult to standardize based on varying international hospital practice policies for discharge. Table 15A.2 shows a range of 1.6 to 12 days in the LRP group, while a range of 1 day to 5.5 days is reported for RALP in Table 15A.1. In the combined series (Table 15A.3), there is no significant difference between the number of days spent in the hospital between the LRP and RALP groups.

15A.1.5. Functional Outcomes

Data for continence and potency are currently not mature enough for RALP to form adequate conclusions when comparing to LRP. Continence outcomes for LRP can be seen in Table 15A.2 and range from 56% to 100%. The definition of continence by pad number varies from series to series, therefore making adequate comparison difficult. Similar problems exist with regards to erectile dysfunction. Table 15A.2 shows a range of 25% to 82% depending on the type of preservation performed and the use of medications. Therefore, longer follow-up with standardized reporting is vital for true comparisons to be made.

15A.2. Conclusion

Robotic-assisted laparoscopic prostatectomy appears to be very well tolerated with the rates of peri-operative morbidity that are comparable to those of standard LRP. With the benefits of a shortened learning curve, three-dimensional visualization, and six degrees of freedom of movement, RALP may offer the advantages of less intraoperative blood loss and shorter operative times when compared to standard laparoscopy. Additional series and the further maturation of existing data is necessary to strengthen these conclusions.

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15B

The French Experience: The St. Augustin Transition from the Laparoscopic to the Robotic Approach

Thierry Piechaud, A. Pansadoro, and Charles-Henry Rochat

15B.1. Introduction

In 1997, we performed the first standard laparoscopic radical prostatectomy with a posterior approach to the seminal vesicle at the St. Augustin Clinic. After eight years and more than 3000 patients operated on we arrived at a steady state. As a center of excellence, we personally found that it was not possible for our technique to evolve any further. This was secondary to the technical limitations on standard laparoscopy, two-dimensional (2D) vision, counterintuitive motion, and nonwristed instrumentation. The arrival of robotic technology at our institution in January 2006 began a new era in our approach to radical prostatectomy. We thought that the quality of the vision provided by the robot with a three-dimensional (3D) image and the possibility of working using six axis instruments could help us in overtaking the technical limits of laparoscopic surgery.

In this chapter, we present our thoughts on the key differences and the technical evolution from laparoscopic to robotic radical prostatectomy.

15B.2. Trocar Position

For both approaches, robotic and laparoscopic, the procedure can be performed either in a transperitoneal or in an extraperitoneal way.

In laparoscopy, there is no real difference between the extra- and the intraperitoneal appraoch, but for robotic prostatectomy we suggest a transperitoneal access. It offers the advantage of a wider working space and offers more comfortable placement of the six trocars.

The position of the trocars differs totally from one technique to the other. In laparoscopy we routinely use five trocars; with the robot we need six trocars (four for the robot and two for the assistant). In laparoscopy we place one 10-mm port for the optics at the navel, and four 5-mm ports are distributed as follows: One in the left iliac fossa and one in the midline between the umbilicus and the pubis bone (used by the surgeon), one in the right iliac fossa, and another four fingers above the last (used alternatively by the assistant; Figure 15B.1)

Using the da Vinci® robotic system (Intuitive Surgical Inc., Sunnyvale, CA), according to surgeon's preferences we adopted two different positions of the trocars. A 12-mm trocar is placed on the superior border of the navel. It will be used to insert the 0° optic. The right robot trocar (yellow arm, no. II) is placed at the midline between the anterosuperior iliac spine and the navel. Two 5-mm trocars are positioned on both sides of this one, about 5 cm proximally. They will be used by the assistant. Two left robot trocars are inserted in the left iliac fossa (red arm, no. IV) and in the middle between this one and the optical trocar (green arm, no. III; Figure 15B.2).

Alternatively, the right trocar is placed 2 cm superiorly at the iliac crest and the two 5-mm trocars used by the assistant are positioned

Figure 15B.1. Position of the trocars for the laparoscopic approach.

between this one and the optical trocar, approximately 5 cm above (Figure 15B.3).

In robotic and laparoscopic prostatectomy, the pneumoperitoneum is created in the same way: a Veress needle is inserted at the navel and the patient is inflated. The pneumoperitoneum is pressurized to 12 mm Hg. Only at this moment do we begin to insert the trocars.

15B.3. Dissection of the Neurovascular Bundles

In this step, the 3D vision provided by the two 6-mm optics of the robot enhances every detail. With the robot it is possible to dissect and clip every small perforating artery going to the prostate and to separate out the bundle from the prostatic surface.

The last lateral attachments of the bladder to the prostate are transected. The prostate is grasped and suspended in an upper position with arm IV. In this procedure, arm IV has a main role. It allows the surgeon to avoid any traction and any traumatic injury to the bundles. The fourth arms stays static but can be used to orient the prostate in different ways. By these maneuvers and thanks to the imaging of the robot, the dissection is performed in a more precise and accurate way.

In laparoscopy, it is the assistant that has to play the role of the fourth robotic arm. He or she grasps the prostate to expose it. Obviously a certain traction on the organ must be applied and the assistant cannot stay blocked in a fixed position for a long time. A traction toward the left is applied during the dissection of the right neurovascular bundle and vice versa. Usually we begin with the right nerve. The prostatic pedicles are dissected carefully and meticulously with the cold scissors. All the small arteries in the middle of the fatty tissue going to the prostate are prepared, clipped, and transected. This is the most difficult part of the procedure. During this step the assistant simultaneously utilizes the suction, to expose and to suck, and the endoclips. On the other hand, in laparoscopic prostatectomy it is always the surgeon who alternates clips and scissors with his right hand.

We use 5-mm and 2.5-mm clips in laparoscopy and in robotic procedures, respectively. The

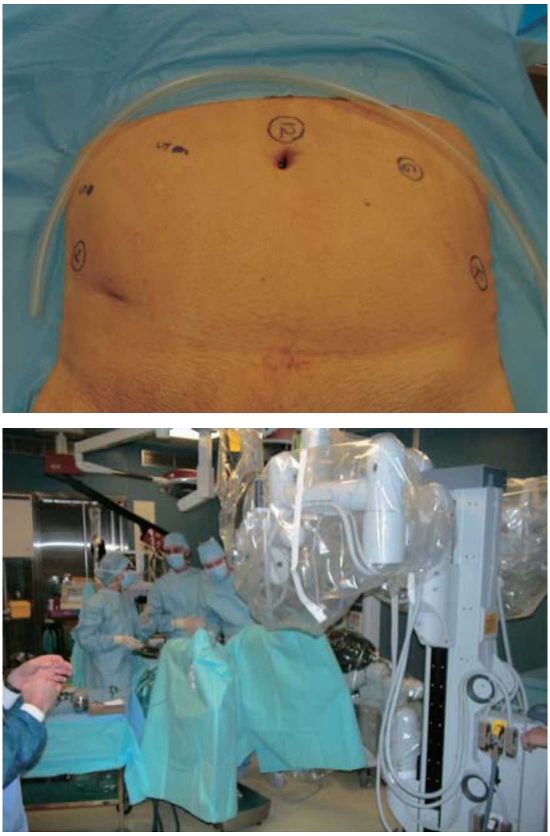

Figure 15B.2. and **Figure 15B3.** Different positioning of the trocars in robotic prostatectomy according to surgeon's preferences.

quality of the vision and of the dissection performed with the robot lets us apply clips smaller than in the laparoscopic approach. The only way to perform this dissection correctly is to proceed millimeter by millimeter. The bipolar is used only to improve the exposition of the bundles. Once again no source of energy is used at this time, because it has been proven to injure the bundles.

Regarding clinical stages of the tumor, the dissection can be performed in two different planes: between the periprostatic fascia and the prostatic capsule (intrafascial dissection, for T1c) (Figure 15B.4); between the bundle and the periprostatic fascia (interfascial dissection, T2a).

Little by little we reach the posterolateral angle of the prostate. Now the fatty tissue is no longer present and the dissection up to the prostate apex becomes easier. The endopelvic fascia is opened on the superolateral part of the prostate. Our way to proceed is always the same: millimeter by millimeter all the perforating arteries to the prostate are isolated. At this time it is not always possible to clip these small vessels because of the narrow space, thus we prefer to cut them and to accept a small amount of bleeding.

This step is repeated in the same way on the left neurovascular bundle.

15B.4. The Anastomosis

The anastomosis is performed in the same way in robotic and in laparoscopic radical prostatectomy. For beginners, the 3D vision and the multiple orientation of robotic needle drivers allow the anastomosis to be performed in an easier and faster way than in laparoscopy.

The urethrovesical anastomosis is performed with a running suture. A 20-cm 3-0 monofilament (23-mm needle) and a 15-cm 3-0 monofilament (26-mm needle) suture are adopted in the robotic and in the laparoscopic techniques, respectively. We always begin the anastomosis at three o'clock on the bladder and we perform it in a clockwise direction, with six passages, ending at two o'clock (Figure 15B.5). The catheter is used to better visualize the lumen of the urethra. After every passage the assistant grasps the suture to prevent any loss of tension.

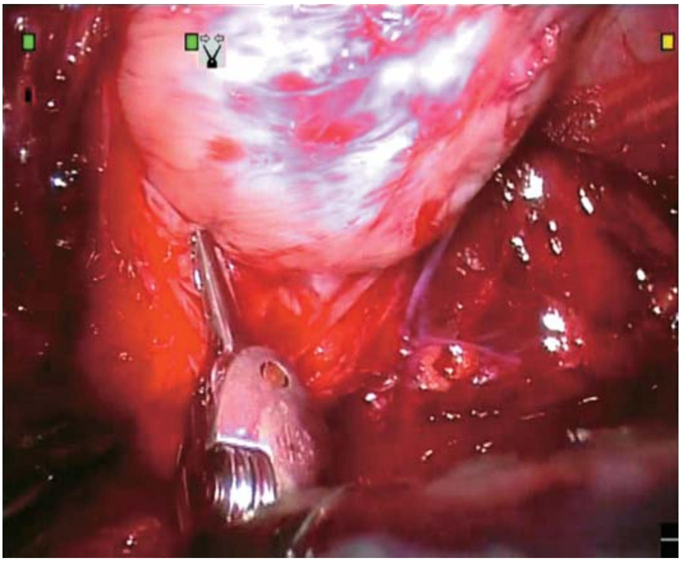

Figure 15B.4. Intrafascial dissection of the right and left neurovascolar bundles.

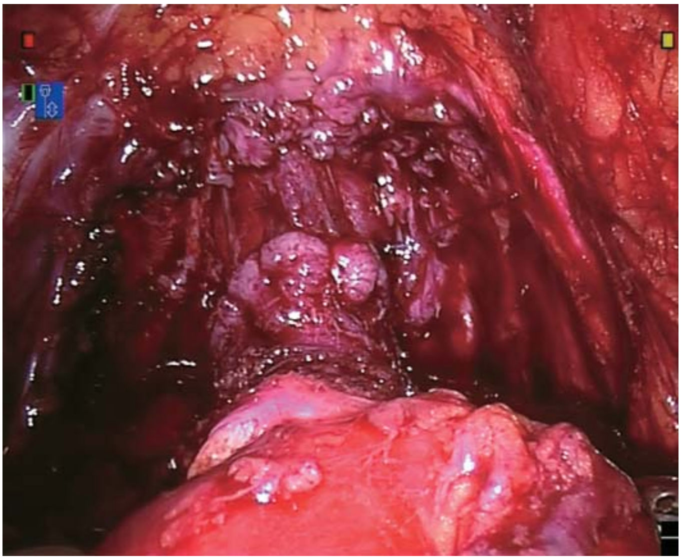

Figure 15B.5. Intrafascial dissection of the right and left neurovascolar bundles.

At the end of the suture the balloon of the catheter is inflated to 10 cc and a water tightening test with 150 cc saline solution is done.

15B.5. Conclusion

Our extensive experience with standard and robotic laparoscopic prostatectomy has been rewarding. We reached proficiency with the standard approach but soon found a plateau in our technical evolution due to the limitations of the instrumentation. We have found that robotic technology can easily be adapted and offers significant benefits which can be utilized to allow the technique of radical prostatectomy to evolve to an even higher level.

16

The Oncologic Outcomes of Robotic-Assisted Laparoscopic Prostatectomy

Kristy M. Borawski, James O. L'Esperance, and David M. Albala

Whenever a new procedure is introduced, it is imperative that it offers the same or improved outcomes compared to the gold standard. This is especially true when one is dealing with oncologic outcomes. Proponents of robotic surgery are in favor of its three-dimensional (3D) visualization, wristed instruments, finger-controlled movements, seven degrees of freedom (six degrees and freedom of grip) as well as tremor elimination.[1–6] With these advantages there a is a possibility of increased precision and improved oncologic outcomes. One disadvantage, however, is the lack of tactile feedback.

16.1. Open Radical Prostatectomy

16.1.1. Margin Status

Even with the technological advances in the field of prostate cancer surgery, radical retropubic prostatectomy (RRP) remains the gold standard to which all other operative interventions must be measured.[7–12] Rates for positive margins vary considerably throughout the literature. Wieder reported an average margin positive rate of 28% for RRP with a range of 0% to 71%.[13,14] Other series have reported positive margin rates from 2.9% (for pT2 disease) to 39%.[15–19] When stratified by clinical stage, the average rate for positive margins was 5% for T1a, 22% for T1b, 23% for T1c, 17% for T2a, 36% for T2b, and 40% for T3a. The mean rate of positive surgical margins for T1 disease was 21%, 29% for T2 disease, and 53% for T3 disease.[13]

The apex of the prostate is the most common site of a positive surgical margin.[17] Blute and coworkers examined the location of positive margins in 2334 patients with organ-confined disease after RRP. They found 58% of the positive margins were located at the apex, 19% at the base, 2.5% at the anterior portion of prostate, and 40% at the posterior portion of the prostate. This was associated with a five-year progression-free biochemical failure rate of 79%, 78%, and 56% for positive margins located at the apex, anterior/posterior, and base, respectively.[6,20]

16.1.2. Progression-Free Survival

Although it is still debated in the literature, there is an abundance of evidence that supports the theory that a positive surgical margin is associated with an adverse outcome of progression-free probability.[13,15,17,21] Five- and ten-year progression-free survival after open prostatectomy does seem to be impacted by margin status. Five-year survival decreases from 47% to 94.6% for those with negative margins to 6% to 86% in patients with positive margins.[13] Epstein and colleagues reported a 10-year progression-free survival for patients with both negative and positive surgical margins of 79.4% versus 54.9%, respectively.[13,22]

16.1.3. Risk Factors for Positive Margins

Irrespective of the surgical approach, tumor stage, volume of disease, high preoperative prostate- specific antigen (PSA) value, and a high

Gleason score have all been shown to be predictive of a positive surgical margin after surgery.[13]

16.2. Robotic-Assisted Laparoscopic Prostatectomy

16.2.1 Initial Results

The largest series of robotic-assisted laparoscopic prostatectomies originates from the Vattikuti Urology Institute in Detroit, Michigan. Their initial experience began independently in June 2001.[23] Evaluation of Menon's initial 40 cases demonstrated an overall margin positive rate of 17.5% (71.4% of these were focal; 28.6% were extensive) and 95% (39/40) of his patients achieved an undetectable postoperative PSA value. Margin rate in this study was not stratified by pathologic stage or the location, nor was the pathological technique described.[24]

Data from 45 robotic-assisted laparoscopic prostatectomy (RALP) procedures from the University of California, Irvine, demonstrated an overall positive surgical margin rate of 35.5% (16/35). In these cases, 50% were located at the apex, 37% were located at the lateral margins, and 12.5% were located at the bladder neck, respectively. Further stratifying margin status by pathologic grade revealed a positive margin rate of 64.7% (11/17) for patients with pT3 or higher disease. For organ-confined disease (pT2 or less), the rate of a positive margin was 14.2% (4/28).[14]

Data from Europe closely mirrors that from the Unites States. In their initial experience, Abbou demonstrated the feasibility of an extraperitoneal approach for RALP in four patients. One of these patients (Gleason 3+4, pT2b, PSA 24) had a positive apical margin for a positive margin rate of 25%.[25] The same group then published their results after 11 patients consecutively underwent a RALP. Three patients in this series had focally positive lateral margins, for a rate of 27.3%, although no information is available on their pathologic stage.[26] Pasticier and colleagues then published their series of six patients, all of whom had organ confined pT2 disease and demonstrated a margin positive rate of 20%.[27]

Binder had a 33.3% margin-positive rate in his initial series published in 2001. Ten patients, three of whom had received neoadjuvant hormonal therapy, underwent RALP, with the final pathology revealing pT3 or higher in four patients. No patient with pT2 disease had positive margins (two positive margins with pT3a and one with pT3bN1 disease).[28] Binder followed his feasibility study with a series containing 40 patients who underwent RALP. Overall, 30% of patients had a positive margin; however, the location of the positive margins was not reported. Stratified by stage, positive margins were found in 10% (2/25) of patients with pT2 disease and 67% (10/15) of patients with pT3 disease. An average postoperative (day 14) PSA value of 0.32 ± 0.48 was listed, although no further follow-up PSA values were published.

16.2.2. Larger Series

The Vattikuti Institute reported on the outcomes of their first 100 patients undergoing RALP between August 2001 and May 2002. They reported a 15% incidence of positive margins at the inked margin of the surgical specimen; three patients had multiple site involvement. Sixty-six percent (12/18) of their positive margins were located at the apex (nine focal, three nonfocal), 27.8% (5/18) at the posterior aspect of the prostate (all nonfocal) and 5.6% (1/18) located at the bladder neck (focal). Four of their patients with positive margins had T3b disease; however, the remaining pathological stage distribution amongst those with positive surgical margins is not mentioned nor was there any follow-up PSA data.[29]

The next publication from this institution evaluated the results of Menon's last 200 RALP procedures. In this series, 86.8% of tumors were pT2 disease while 13.1% were pT3. One patient had positive lymph nodes at the time of pathologic examination. Six percent of his patients had a positive surgical margin. However, it is important to note that in this series, apical margins were considered positive only if the distal margin of the apical biopsy, not the inked prostate specimen, were positive for cancer. Six months postoperatively, 92% of his RALP patients had an undetectable PSA.[4]

Again, the European data closely mirrors that of the United States for series in which positive margins were defined as the presence of tumor at the inked margin of the surgical specimen, not apical biopsies. The Montsouris group demonstrated a 22% positive margin rate in their experience of 105 patients. Twelve percent of pT2 patients had a positive surgical margin, while 43% of pT3 patients had a positive surgical margin. The locations of the margins as well as delineation between focal and extensive margins are not available. Ninety-eight percent of the 105 patients had a postoperative PSA level less than 0.2 ng/mL.[30]

Data from Frankfurt (Wolfram et al.) examined the last 81 patients from their 118 patient series who underwent a RALP using the modified descending Montsouris technique. A positive margin was identified in 18 of the 81 patients (22.2%). Seven patients (12.7%) with organ-confined disease (pT2) had positive surgical margins, while 11 (42%) of patients with pT3 tumors had positive surgical margins. Neither the location of the positive margins nor follow-up PSA data was provided in this series.[12]

Patel and colleagues documented their experience with 200 RALP in the community setting in a recent publication. Using the presence of cancer at the inked margin of the surgical specimen, he reported a positive margin rate of 10.5% for the entire series. Six percent of patients with pT2 disease had a positive margin, 28.5% for pT3a disease, 20% for pT3b disease, and 33% for patients with pT4a disease. Stratified by location, the majority, 11 (52.4%) were located laterally, 4 (19%) were located at the apex, 1 (4.8%) was located at the bladder neck, while 5 (23.8%) were multifocal. When stratified by case number, the first 100 patients had a 13% rate of positive margins while the second 100 patients had a positive margin rate of 8%. At an average follow-up of 9.7 months, 95% of patients had an undetectable PSA (<0.1 ng/mL). No patients with pT2 or pT3a disease with only focal extracapsular extension had a PSA recurrence. Early biochemical recurrence was detected in 2% of patients.[31]

In unpublished data, Patel examined the results of 500 patients who underwent RALP and found a positive margin rate of 9.4% (47 positive margins) for the entire series. When stratified by case number, cases 1 to 100, 101 to 200, 201 to 300, 301 to 400, and 401 to 500 had a positive margin rate of 13%, 8%, 13%, 5%, and 8%, respectively. Further dividing the data by stage, the margin positive rate for T2a was 2%, 4% for T2b, 2.5% for T2c, 24% for T3a, 40% for T3b, and 63% for T4a. Tumors that were organ confined had a margin positive rate of 2.5% versus 31% for tumors not confined to the prostate. Fifty-six percent of the positive margins were located posterolateral, 8.5% apical, 8.5% at the bladder neck, 4% at the seminal vesicle, and 23% were multifocal (V.R. Patel, personal communication, 2005).

16.3. Techniques to Decrease Positive Margins

As noted earlier in this chapter, the apex is the most common site of positive surgical margins in open prostatectomy specimens. Robotic-assisted laparoscopic prostatectomy provides superior visualization of the prostatic apex with the added benefit of decreased bleeding from the dorsal venous complex. The urethra can be incised more precisely, thus potentially decreasing the number of positive apical margins. In addition, the posterolateral prostate is well visualized during a RALP, leading to easier identification of the plane between the neurovascular bundles and the prostatic capsule.[32] In spite of this, however, many of the reported series have shown the lateral aspect of the prostate to be the most common area of a positive surgical margin.

Ahlering described a technique aimed at reducing pT2 positive margins in 2004. After reviewing video documentation of the cases in which patients had a positive margin, a new technique was fully implemented after 50 cases. This technique involved removing all overlying fat from the puboprostatic ligaments and the dorsal venous complex (DVC), allowing for more precise visualization of the entire surface of the prostate. After incision of the endopelvic fascia and mobilizing the prostate, the second technique alteration involved the division of the puboprostatic ligaments and dissection of the levator fibers adherent to the DVC. Ahlering then compared his first 50 cases (reported above) to cases 51 to 140 to evaluate this new technique. The second group (cases 51–140) had a significantly decreased margin positive rate compared to the first group (cases 1–50), 16.7% versus 36%. It is important to note that both groups had similar preoperative oncologic characteristics. Group one had a higher rate of positive margins for pT2 disease as compared to group 2 (9/33 or 27.3% vs. 3/64 or 4.7% of all positive margins, $p = 0.003$). There was no difference in the positive margin rate for pT3 disease between the two groups (group 1, 8/16 or 50%; group 2, 11/25 or 44%). Three-month PSA data were available for 114 of the 140 patients. Thirteen patients had an elevated PSA (PSA > 0.1 ng/mL); nine of these patients were in group 1. Two patients with pT2 disease in group 1 had an elevated PSA. In these two patients, one had a positive surgical margin. No patient with pT2 disease in group 2 had a PSA recurrence (data was available on 64/90 patients in group 2).[33,34]

16.4. Robotic-Assisted Laparoscopic Prostatectomy: Comparison to Open and Laparoscopic Prostatectomies

16.4.1. Robotic-Assisted Versus Pure Laparoscopic Prostatectomy

One series (Joseph et al.) compared 50 patients undergoing a pure laparoscopic prostatectomy versus 50 patients undergoing RALP. Preoperative characteristics were similar between the two groups and one team of genitourinary pathologists evaluated each specimen. The margin-positive rate did not differ significantly between the pure laparoscopic and the RALP group (14% vs. 12%, respectively). In addition, after a mean follow-up of 5.3 months (range, 2–9 months), there were no biochemical recurrences.[35]

Published margin positive rates for pure laparoscopic prostatectomy do not seem to differ from those of RALP.[35–39] Margin-positive rates ranging from 11.4% to 34% (for the entire series) have been reported, similar to those listed above for entire RALP series.[33,36–39]

16.4.2. Robotic-Assisted Laproscopic Prostatectomy Versus Radical Retropubic Prostatectomy

Menon initially described a prospective, non-randomized trial comparing outcomes for RALP versus RRP. Of the 30 patients who underwent RALP, 26% (12% focal and 14% extensive) had positive margins versus 29% (14% focal and 15% extensive) in the retropubic group (p = not significant). This data represents the initial RALPs performed at the Vattikuti Institute.[8]

The Vattikuti team then published their prospective results of 100 patients undergoing a retropubic prostatectomy and 200 undergoing a RALP. Twenty-three percent of the patients who had a RRP had a positive surgical margin versus 9% of the RALP patients ($p < 0.05$). It is important to note, however, that the apical margin was considered positive in the RALP group only if tumor was noted at the distal end of the apical urethral margin, not on the inked surgical specimen as in the retropubic group.[7]

Ahlering then reported on a prospective series in which one surgeon performed both the RALP and the RRP procedures. Sixteen percent of patients undergoing a RALP had a positive surgical margin compared to 20% of those undergoing a RRP. Five percent of patients with pT2 disease in the RRP group had a positive margin versus 9.1% in the RALP group. The incidence of positive margins in pT3 disease was the same in both groups (50%). This series had identical definitions for positive margins as compared to the previous study, thus eliminating that as a potential source of bias.[40]

16.5. Conclusion

As with any new oncologic procedure, it is imperative that it meet or exceed the efficacy of the gold standard operation. With regards to RALP, although only early results are available, it appears that it will have the same efficacy as the gold standard, RPP with regards to surgical margin status and early PSA data. However, long-term follow-up data is needed to assess recurrence rates.

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17

Anatomic Basis of Nerve-Sparing Robotic Prostatectomy

Sandhya Rao, Atsushi Takenaka, and Ashutosh Tewari

It is estimated that, in 2005, prostate cancer will be diagnosed in over 232,090 men in the United States and that 30,350 men will die from the disease.[1] Radical retropubic prostatectomy offers an effective cure,[2–4] but is associated with significant postoperative morbidity, including erectile dysfunction and incontinence.[5,6] The development of nerve-sparing anatomic prostatectomy by Walsh and colleagues has lead to improved potency rates.[7,8] However, the results regarding potency preservation published in the literature by many centers are not satisfactory.[5,6]

Identifying and sparing the neurovascular bundle on one or both sides is crucial in maintaining erectile function. The road map for nerve sparing during radical retropubic prostatectomy was laid down by Walsh.[7,9] Several excellent monographs, textbooks, and artist-drawn figures explaining the detailed course of the neurovascular bundles are available based on the initial anatomic dissections.[7,8,10–12] In recent years, a few centers have attempted nerve-sparing anatomic prostatectomy using conventional and robotic-assisted laparoscopic approaches.[13–25] The surgical steps for these minimally invasive approaches differ significantly from the conventional radical prostatectomy for which most existing anatomical descriptions have been done. Laparoscopic and robotic prostatectomies are performed in an antegrade manner, while conventional radical retropubic prostatectomy is often performed in a retrograde manner (i.e., transection of the urethra prior to bladder neck disconnection from prostate).

Therefore, these anatomic principles need to be re-emphasized in the context of robotic surgery because surgical steps are reversed, visual angles are different, and magnification and stereoscopy provide more detailed anatomic images than that seen by surgeons during open surgery. The aim of this chapter is to highlight prior knowledge about anatomic and robotic prostatectomy and introduce some new concepts with the hope that it will benefit new surgeons attempting nerve-sparing robotic radical prostatectomy.

17.1. Pelvic Neuroanatomy

17.1.1. Pelvic Plexus

The pelvic splanchnic nerves arise from the anterior sacral roots, with most branches originating from S4 and smaller contributions from S2 and S3. These parasympathetic fibers converge with sympathetic fibers from the hypogastric nerve to form the pelvic plexus (Figures 17.1 and 17.2) The pelvic plexus is rectangular, approximately 4 to 5 cm long, and its midpoint is at the tips of the seminal vesicles. It is retroperitoneal, fenestrated, and located on the anterolateral wall of the rectum. It is pierced by numerous vessels going to and from the rectum, bladder, seminal vesicles, and prostate. The superior part of the plexus is arbitrarily called the vesical plexus and the inferior part the prostatic plexus. Each ganglion of the plexus contains about 20 nerve cell bodies.[26]

On the surface of the rectum are cross-connections between the nerve branches of the two sides. The pelvic plexus provides visceral branches that innervate the bladder, ureter,

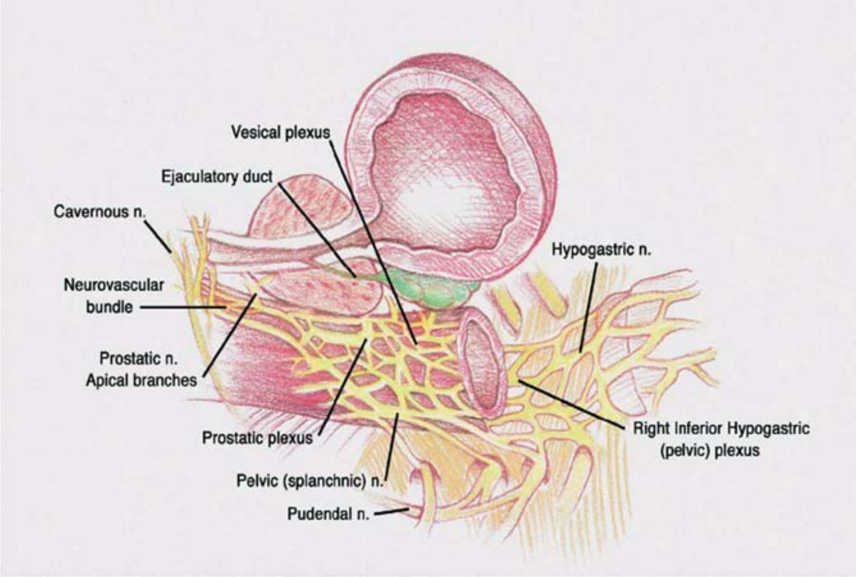

Figure 17.1. Schematic representation of pelvic neuroanatomy. (Reprinted from Terwari A, Peabody JO, Fischer M, et al. An operative and anatomic study to help nerve sparing during laparoscopic and robotic radical prostatectomy. Eur Urol 2003;43:444–454, with permission from the European Association of Urology.)

seminal vesicles, prostate, rectum, membranous urethra, and corpora cavernosa. The branches of the inferior vesical artery and vein that supply the bladder and prostate perforate the pelvic plexus. For this reason, ligation of the so-called lateral pedicle in its midportion not only interrupts the vessels but also transects the nerve supply to the prostate, urethra, and corpora cavernosa.[27] According to Costello and colleagues, the branches of the pelvic plexus form three major projections: (1) anterior across the seminal vesicles and the inferolateral surface of the bladder, (2) anteroinferior across the lateral surface of the prostate, and (3) inferior between the posterolateral wall of prostate and rectum, which unites with several vessels to form the neurovascular bundle (NVB).[28] Recently, Tewari has described the concept of the proximal neurovascular plate (PNP) as a spraylike structure chiefly composed of the vesical and prostatic subdivisions of the pelvic plexus; however, it is also composed of ganglions and interconnecting nerve fibers.[29] It forms an integrating center for the processing and relay of erectogenic neural signals. The PNP extends lateral to the base of the prostate and bladder neck and converges to continue as the classical NVB, while a few branches traveled through the fascial and capsular tissue of the prostate as accessory pathways.

17.1.2. Neurovascular Bundles

The inferior extension of the pelvic plexus unites with several vessels to form the neurovascular bundle (NVB) of Walsh. Classically, this been described as a tubular structure running along the dorsolateral aspect of prostate gland enclosed in fascial sheaths and intimately associated with the capsular vessels of the prostate. Tewari and colleagues have shown that the NVB, which they

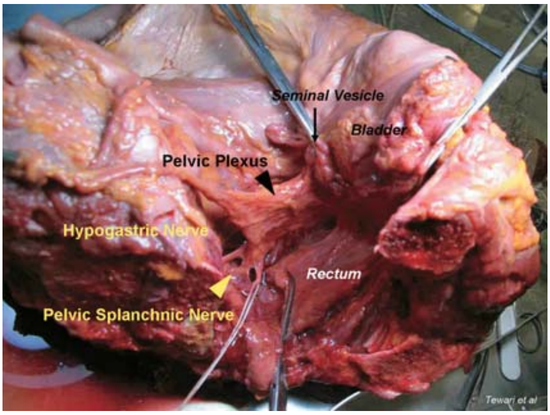

Figure 17.2. Anatomic dissection male pelvis showing cut rectum, bladder, and seminal vesicle. The hypogastric nerve joins the pelvic splanchnic nerve to form the pelvic plexus.

have termed the predominant neurovascular bundle (PNB) varies in its shape, size, and course from the proximal to distal end.[29] It is thickest at the base and most variable in course and architecture near the apex. In their studies, in 65% of cases there was a medial extension of this bundle behind the prostate, which in 30% of cases converged medially near the midline at the apex of the prostate (Figure 17.3). On branching from the pelvic plexus, these nerves in the NVB are spread significantly with up to 3 cm separating the anterior and posterior nerves.[28] The anterior nerves course along the posterolateral surface of the seminal vesicle and the posterior nerves run dorsal to the posterolateral verge of the seminal vesicles. The nerves of the NVB converge at the mid-prostatic level and diverge again when approaching the apex. Because the bulk of the pelvic plexus is lateral and posterior to the seminal vesicles, they are an important anatomic landmark during surgery to avoid injury to the plexus.

The terms *cavernosal nerve* and *the NVB* are often used interchangeably. However, multiple recent studies have shown that the anatomy of the NVB may be more complex than initially thought.[26,30] Though the classical thinking is that the surgically identified NVB contains the cavernous nerve, in reality there may be a plexus of nerves innervating the cavernosal tissues, rectum, and prostate. Many anatomic studies have suggested that in addition to the main NVB, multiple accessory channels exist that ramify in the prostatic and Denonvillier's fascia and which supply neural stimulation to the penis.[26,30,31] These accessory pathways are seen both anteriorly and posteriorly usually as extensions from the proximal neurovascular plate.[26] These accessory fibers, which form an apical plexus on the posterolateral aspect of the prostatic apex and urethra, could potentially act as a neural pathway for not only cavernous tissue but also the urethral sphincter (Figure 17.4)

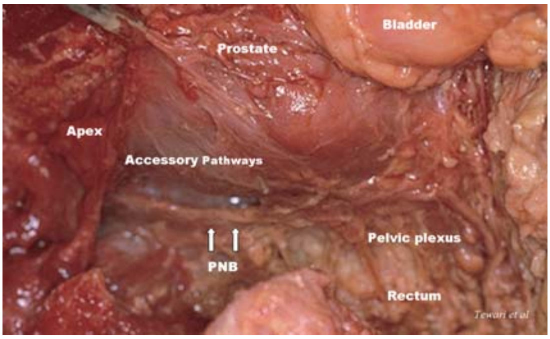

FIGURE 17.3. Anatomic dissection showing the pelvic plexus, the predominant neurovascular bundles (PNB), and accessory neural pathways. It also shows the position of the PNB in relation to prostate and rectum.

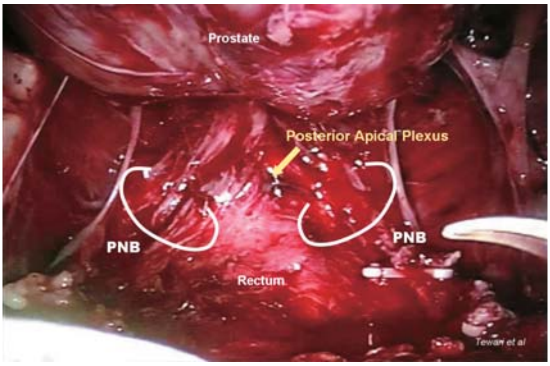

FIGURE 17.4. Intraoperative photograph showing the posterior apical plexus.

According to Takenaka and colleagues, the cavernous nerve arises from the most caudal components of the pelvic splanchnic nerves which form the pelvic plexus.[30] They showed that at the level of the prostatovesical junction, the thick identifiable branches of the NVB originate from the hypogastric nerve. The hypogastric nerve contains abundant parasympathetic ganglion cells that provide neural stimulation to the penis sufficient to maintain erectile function. At this level, the NVBs do not contain the caudal branches of the pelvic splanchnic nerves which reach the posterolateral aspect of the prostate more than 2 cm below the junction. Thus, at this level of the prostatovesical junction, the surgically defined NVB may not contain the cavernous nerve.

Near the apex, the bundles are covered with fascial layers and classically described as lying at five and seven o'clock position around the urethra. Takenaka and colleagues showed that there was statistically significant variation in the course of the cavernous nerve near the apex of the prostate.[32] The cavernous nerves caudal to the prostate are not only lateral but also dorsal to the membranous urethra. Only the area of the dorsal median raphe of the rhabdosphicter contains no nerves.[33]

There is debate as to whether the NVB also contains the nerves responsible for continence. Strasser and colleagues proposed that the NVB contains motor and sympathetic fibers to the rhabdosphincter.[34] Takenaka and colleagues described twigs to the rhabdosphicter from a nerve bundle from the sphlancic nerve that contained thick myelinated fibers responsible for motor innervation of the sphincter.[32] Recent studies concluded that the somatic and autonomic nerves follow different courses.[35–37]

17.1.3. Periprostatic Fascia

A knowledge of the fascia of this area is required to understand the neuroanatomy of the prostate. Posteriorly between the prostate and the rectum lies the Denonvillier's fascia a multilayer composed of collagenous fibers and occasional muscle fibers. The Denonvillier's fascia fuses with the prostatic capsule at the center of the posterior aspect of the prostate. Posterolaterally, the Denonvillier's fascia and the prostatic capsule are clearly separated by adipose tissue, but linked with each other by delicate fascicles.[31] The prostate gland is covered by the prostatic capsule and the periprostatic fascia.

The NVB runs along the posterolateral aspect of the prostate enclosed within the layers of the periprostatic fascia [Figure 17.5(A,B)]. The inner layer is called the prostatic fascia and the outer layer is called the lateral pelvic fascia. The prostatic fascia is a multilayer fascia with collagenous fibers, muscle, venous sinuses, and neurovascular elements. It is intimately attached to the prostatic capsule. The layers of the periprostatic fascia fuse with the anterior layer of Denonvillier's fascia lateral to the prostate to form a potential triangular space containing the NVBs. The inner layer of the periprostatic fascia forms the medial vertical wall of this triangle; the outer layer or the lateral pelvic fascia forms the lateral wall and the anterior layer of the Denonvillier's fascia forms the posterior wall. The triangular space is wide near the base of the prostate and narrow at the apex. The neurovascular bundles in this space are covered by the superficial layers of Denonvillier's fascia that fuse with the posterior limits of levator fascia. Along the course of the bundles, micropedicles are found consisting of tiny vessels and nerves that supply the adjacent prostatic capsule and tether the bundles to the posterolateral surface of the prostate.

17.2. Nerve-Sparing Technique of Robotic Prostatectomy

Based on the above anatomical description, it is seen that the neural mechanism is at risk in most steps of robotic prostatectomy. Further discussion will focus on the specific steps of a robotic prostatectomy. These include bladder mobilization, exposure of prostatic apex and incision of endopelvic fascia, control of the dorsal venous plexus, transection of anterior and posterior bladder neck, dissection of vas and seminal vesicles, control of lateral pedicles, nerve sparing, apical dissection, and urethrovesical anastomosis.

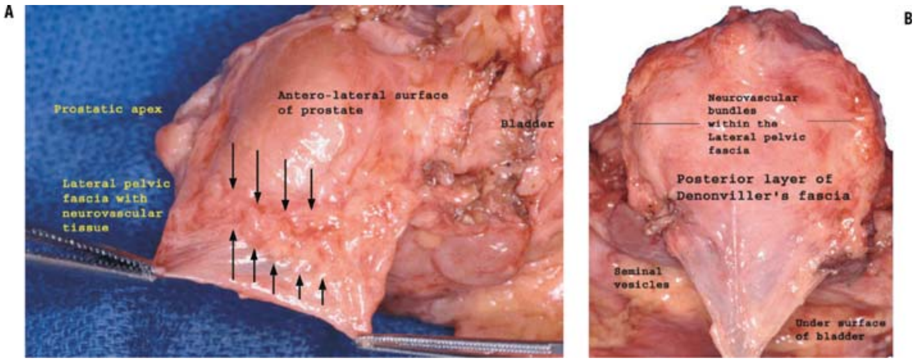

Figure 17.5. Anatomic dissection showing the lateral pelvic fascia. (A) Lateral surface of prostate showing small and large nerves. (B) Undersurface of prostate showing Denonvillier's fascia and nerves. (Reprinted from Terwari A, Peabody JO, Fischer M, et al. An operative and anatomic study to help nerve sparing during laparoscopic and robotic radical prostatectomy. Eur Urol 2003;43:444–454, with permission from the European Association of Urology.)

17.2.1. Dissection of Endopelvic Fascia

The initial steps of bladder mobilization and creation of space of Retzius are relatively safe. However, dissection of the endopelvic fascia puts the proximal neurovascular plate and neurovascular bundles at risk of traction, blunt injury, or coagulation injury. This can be prevented by the athermal technique of robotic prostatectomy previously described by Tewari and colleagues using sharp dissection.[38]

17.2.2. Dorsal Venous Stitch

The accessory pathways near urethra are at risk during deep placement of the dorsal venous (DVP) stitch.[29] This can be avoided by placing the stitch later prior to disconnection of the apex when the prostate is relatively free and the venous complex can be better visualized.

17.2.3. Bladder Neck Transection and Dissection of Vas and Seminal Vesicle

Caution is needed at the time of bladder neck transection, especially if started laterally. The pelvic plexus is located laterally and overzealous dissection will place it at risk. Preventive measures include using the bladder neck pinch technique for identifying the bladder neck and limiting dissection to the anterior third of the prostatovesical junction.[26] Next, the vasa are identified in the window behind the retrotrigonal layer, a consistent fibromuscular sheet is found posterior to the bladder neck and is dissected using scissors and forceps. Surrounding vessels are controlled with 5-mm surgical clips. The proximal vas is clipped and divided. The seminal vesicles are dissected similarly and clipped precisely at the surface of the gland to avoid damage to the neurovascular plate. The tip of the seminal vesicle is tethered posterolaterally due to vessels supplying the vesicles and vas. Traction on the seminal vesicles during this dissection may tent the pelvic plexus medially. Therefore, these vessels should be controlled on the surface of the seminal vesicles. The key to successful nerve sparing is meticulous dissection, staying close to the surface of the seminal vesicle and avoiding dissecting the outer layers, clear visualization, control of individual vessels using small clips, and avoiding electrocautery.

17.2.4. Pedicle Control and Release of Neurovascular Bundle

Control of the lateral pedicle is also fraught with danger to the pelvic plexus. With upward traction of the vasa and seminal vesicles, the prostatic pedicle is identified and if easily differentiated from the bundle, then selective clipping or ligation of the prostatic vessels is performed (Figure 17.6). The pedicles are controlled close to the base. Electocautery and mass ligature are avoided and small clips and individual pedicle controls are preferred. In the technique described by Menon and colleagues, the pedicles are not often clipped when they are preserving the lateral periprostatic fascia to avoid injury to the accessory nerves (veil of Aphrodite).[39]

The prostate is retracted on one side and the lateral pelvic fascia is exposed. Entering the triangular space between Denonvillier's fascia, lateral pelvic fascia, and the prostate best preserves the nerves. The surgeon has to reflect the lateral pelvic fascia off the prostate. It is incised in a plane superficial to the prostatic fascia from apex to prostate–vesical junction, always staying parallel to the neurovascular bundles. This maneuver releases the bundles and provides landmarks for later antegrade dissection.

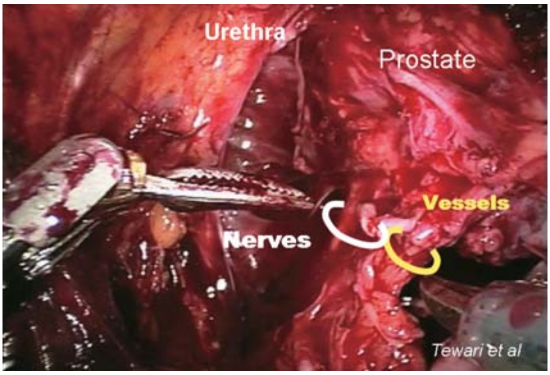

FIGURE 17.6. Intraoperative photograph showing release of the left PNB. The white dashed line shows the approximate boundary between the vascular pedicle medially (circled in yellow) and nerve bundle laterally. (Reprinted from Tewari A, Takenaka A, Mtui E, et al. The proximal neurovascular plate and the tri-zonal neural architecture around the prostate gland: importance in the athermal robotic technique of nerve-sparing prostatectomy. BJU Int 2006;98:314–323, courtesy of Blackwell Publishing.)

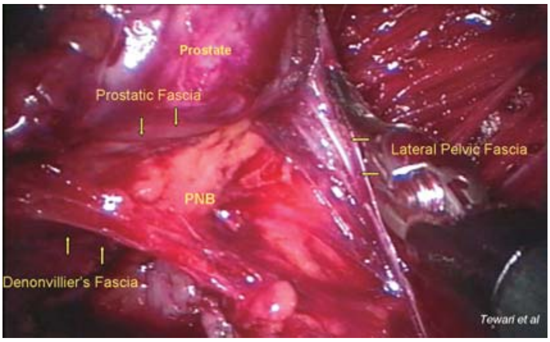

Figure 17.7. Release of the bundle. The PNB is seen in the triangular space bounded posteriorly by the anterior layer of Denonvillier's fascia, medially by the prostatic fascia, and laterally by the lateral pelvic fascia.

17.2.5. Development of the Prerectal Space and Exposure of Neurovascular Triangle

An inverted U-shaped incision is made on the base of the prostate and extended laterally to the prostatic undersurface. Care should be taken to leave both layers of the Denonvillier's fascia on the specimen and expose the prerectal fat. This dissection is continued distally to the apex and laterally over the bundles to expose the neurovascular triangle described above (Figure 17.7) Further dissection proceeds within this triangle to release the bundles staying close to the prostatic fascia. Near the apex a few perforators are clipped and transected, allowing the neurovascular bundles to fall away from the apex.

17.2.6. Apical Dissection and Urethrovesical Anastomosis

The neurovascular bundles and the posterior plexus can be damaged during urethral transection and anastomosis. The visual angles are changed several times to allow identification of both bundles and their relationship with the sphincter. Electrocautery should be avoided and all sutures should be placed under vision.

Enhanced three-dimensional (3D) visualization dramatically improves the identification of various anatomic structures. At the end of a successful nerve-sparing prostatectomy, the pulsations of the vessels in the NVBs in a dry field can act as a surrogate marker for the integrity of the nerves.[26]

17.3. Conclusion

Nerve-sparing principles have been described extensively in several seminal publications.[7,9] The incorporation of these principles in robotic surgery is essential for successful nerve sparing and a good functional outcome. Robotic technology offers an unparalleled view of the male pelvis not seen in open surgery due to magnification and 3D imaging. However, surgeons have to familiarize themselves with the new perspective provided by these improved optics in order to reap the benefits of the improved technology.

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18

Alternative Approaches to Nerve Sparing: Techniques and Outcomes

Can Öbek and Ali Rıza Kural

> Surgery should be a merciful art; the cleaner and gentler the act of operating, the less the patient suffers.
>
> Berkeley Moyhinan

18.1. Introduction

The preservation of sexual potency after prostatectomy has always been the topic of much anxiety and debate. While cancer control and urinary continence are of supreme importance, the preservation of sexual function completes the trifecta that both patient and surgeon strive to achieve. Over the decades open nerve sparing radical prostatectomy has continued to evolve from its early rudimentary beginnings into the more refined techniques that we see today. However, while we have seen considerable advances in recent times the limitations in visualization and dissection of the bundle have continued to provide a challenge to even the most experienced surgeon.

The introduction of robotic assistance into modern day laparoscopic surgery has provided many advantages; the two greatest being improved three dimensional magnified vision and wristed instrumentation. These technical enhancements provide the surgeon with improved surgical tools that have the potential to facilitate a more precise surgical approach. One of the potential advantages during robotic prostatectomy is improving visualization, control and dissection of the neurovascular bundle. In our review, we present the various technical approaches to nerve sparing during robotic radical prostatectomy.

18.2. Nerve-Sparing Techniques and Results

Retrograde neurovascular burdle (NVB) preservation is the most commonly used approach during open nerve sparing radical prostatectomy.[1] This is due to the fact that the procedure is performed in a retrograde manner from apex to base. Laparoscopic prostatectomy has traditionally been performed in an antegrade manner from base to apex due to the improved visualization and appreciation of tissue planes. Therefore, the majority of the laparoscopic approaches to nerve sparing incorporate some form of antegrade dissection. As with any surgical procedure, the technical approach to nerve sparing has been very dynamic and in constant flux. Recently, many centers with expertise in robotic prostatectomy have described their various approaches to nerve sparing.

18.2.1. Categorization of Approaches to Nerve-Sparing Robotic Prostatectomy

The tremendous variability in the approach to preservation of the neurovascular bundle has often led to confusion. This is most commonly due to the fusion of various technical concepts that are used in each individuals approach. While these procedures are often a hybrid of a variety of techniques a few fundamental concepts are apart of everyone's approach. The approach to nerve sparing robotically can be antegrade, retrograde, or a combination of the two. It can be athermal or with the use of thermal energy (monopolar, bipolar, harmonics). Another variable factor is the approach to the fascial layers surrounding the prostate at the site of the neurovascular bundle. The approach can be extrafascial, interfascial, intrafascial, or high intrafascial. We use this basic terminology to define the various approaches to robotic nerve sparing prostatectomy.

18.2.2. Athermal Approaches to Nerve Sparing

It has become increasingly evident that preservation of the nerves may be achieved; yet trauma to the nerves can still diminish, delay, or eliminate recovery of erectile function. It is well known that thermal energy can significantly damage neural tissue. In a canine model. Ong and associates[2] compared monopolar, bipolar and harmonic energy sources with conventional (without energy) dissection of the NVB.[2] Intracavernous pressure was measured immediately and 2 weeks after dissection. Dramatic decreases in intracavernous pressures at both early and late evaluations were shown in all energy groups. In fact, the decrease of intracavernous pressure was >95% in all three energy groups at 2 weeks compared to normal pressures in the conventional and control groups. Of note, studies assessing the impact of energy on nerves have usually used a myelinated nerve such as rats sciatic nerve.[3] The cavernosal nerve, on the other hand, is an unmyelinated autonomic nerve which might be even more vulnerable to heat injury than a thicker myelinated nerve. Temperatures as low as 41°C have proven to damage neural tissue.[4]

18.2.3. University of Chicago Clipless Thermal Antegrade Approach

Investigators from the University of Chicago modified the antegrade method originally described by Kursh and Bodner.[5,6] Upon division through the bladder neck, the plane between both layers of Denonvillier's fascia is identified and developed, separating the prostate from the rectum. Dissection in this plane is carried out distally towards the apex of the prostate. The thick lateral pedicles of the prostate then become prominent on both sides. Using a combination of mostly blunt and some sharp dissection with cold scissors, the vascular pedicles are teased off the prostatic pedicle. Proceeding in a medial-to-lateral dissection in this posterior plane, the vascular pedicles are released prior to the NVBs. The vascular pedicles are further mobilized in an anterior direction until the most distal ends are identified just before penetrating into the prostatic capsule. These small vessels are cauterized at their most distal ends using only bipolar cautery. The vascular pedicles are then swept off the prostate further mobilizing the NVBs, which are then dissected sharply from the prostatic capsule. The dissection continues with peeling off the periprostatic fascia, NVB, and the prostate pedicle en block until the urethra is reached. Bulk clipping of the pedicles is eliminated by dividing them as they enter the prostate because the branches are less then 1 mm in diameter at this level. Dissection with a clipless technique with bipolar energy is similar to that described by Guillonneau and Vallancien; however, Chien and colleagues carry out the dissection from medial to lateral, opposite of the other technique.[7] Alternatively, in an effort to avoid any thermal energy use, clipping of the prostatic pedicles is also a viable option. However, there is then concern that bulk clipping may injure some nerve fibers responsible for erection. Chien and colleagues also propose that after having initially mobilized the NVBs, the thermal spread may be theoretically diminished secondary to the increased distance achieved between the NVB and prostatic capsule. Figure 18.1 depicts bilaterally preserved NVBs during a robotic radical prostatectomy. Using a validated sexual function questionnaire, Chien and colleagues found that, at one month, patients returned to 47% of their baseline preoperative sexual function scores. At 3, 6, and 12 months, this rate increased to 54%, 66%, and 69%, respectively. This was a small series and only six patients reached one-year follow-up.[5]

Figure 18.1. Bulldog clamp in position on right prostate pedicle.

18.2.4. The Henry Ford Technique: The Veil of Aphrodite

The surgeons at Henry Ford Hospital have described an athermal antegrade approach that involves a high intrafascial approach to nerve sparing. The rationale for this approach is based upon new information suggesting that in many instances; a plexus of nerves exists innervating the cavernous tissues, rectum, and prostate in contrast to two distinct NVBs.[8] This plexus crosses the midline posterior within the layers of Denonvillier's fascia and extends to the anterolateral surface of the prostate in the prostatic fascia. The prostatic fascia on the anterolateral surface of the prostate is rich in nerve tissue that may be important in penile erection. Based on these findings, to promote earlier return of potency, investigators from Vattikuti Urology Institute embarked on a feasibility study to examine whether it was technically possible to preserve the prostatic fascia in some men undergoing robotic radical prostatectomy. They have recently published promising results with this new technique.[9,10] Once the seminal vesicles are lifted anteriorly to demonstrate the longitudinal fibers of the posterior layers of Denonvillier's fascia near the base of the prostate, it is incised sharply until prerectal fat is seen. Use of electrocautery is avoided for the entire posterior dissection, so that the NVBs are not damaged by conducted heat. Once the proper plane is entered, the authors dissect between the layers of the Denonvillier's fascia to leave a protective layer of fascia over the rectum and any network of nerves in this area. The plane between the posterior prostate and Denonvillier's fascia is extended as far distally as possible, and then the base of the semial vesicle is retracted superomedially by the assistant, and the prostatic pedicle is delineated and divided. The pedicle lies anterior to the pelvic plexus and NVB, and includes only the prostatic blood supply. Under magnification of the robotic camera, several arterial branches can be seen and controlled individually. The pedicle is divided sharply with cold scissors. The NVB runs along the posterolateral aspect of the prostate encircled by the inner (prostatic) and outer (levator) layers of the prostatic fascia and the posterior layer of Denonvillier's fascia. After dividing the pedicle, the plane between the prostatic capsule and inner leaf of the prostatic fascia is developed at its cranial extent. Once this is accomplished, the assistant provides superomedial prostate retraction and lateral retraction on tissues adjacent to the NVB. This allows the surgeon to enter a plane between the prostatic fascia and the prostatic capsule. The correct plane is between the prostatic venous plexus and the surface of the prostate and is developed with blunt dissection with the articulated scissors, using bipolar coagulation only as necessary. Meticulous sharp and blunt dissection of the NVB and contiguous prostatic fascia is performed until the entire prostatic fascia, up to and including the ipsilateral pubourethral ligament, is mobilized in continuity off the lateral aspect of the prostatic apex. This plane is generally avascular, except anteriorly, where the fascia is fused with the puboprostatic ligament, capsule, and venous plexus. The authors claim that the wrested instrumentation facilitates this dissection, especially in the vicinity of the apex. At the end of a correct dissection, an intact veil of tissue should hang from the pubourethral ligament. The authors state that the thickness and vascularity of the veil is variable. In the presence of large prostates, the veil is delicate, and in men with small prostates the veil is robust and vascular. The authors call this dissected prostatic fascia the "veil of Aphrodite".[9]

In a series comparing various aspects between robotic radical protatectomy (classic nerve sparing) and open radical prostatectomy, investigators from Vattikuti Urology Institute reported potency preservation results in favor of robotic surgery.[11] The odds ratio of median time to erection and to intercourse was 0.4 and 0.5, respectively, when the values for open prostatectomy were used as reference values. More recently, the same group published their results on potency following robotic radical prostatectomy comparing conventional nerve-sparing and prostatic fascia–sparing techniques.[10] A total of 58 potent men with Sexual Health Inventory for Men Score (SHIM) of greater than 21 without phosphodiesterase 5 inhibitors underwent Vattikuti Institute prostatectomy, including 35 with preservation of the fascia and 23 with conventional nerve sparing. Potency was assessed with self-administered SHIM questionnaires 12 months after surgery. The primary endpoint was achievement of erections strong enough for penetration with or without oral medications. At one-year follow-up, 74% of patients in the conventional nerve-sparing group, and 97% of those who underwent the fascia-preserving approach achieved erections strong enough for intercourse ($p = 0.002$). Erections were achieved without the aid of medication in 17% of conventional nerve-sparing group and 51% in prostatic fascia–preserving group. The authors stated that erectile function outcomes achieved with prostatic fascia preservation was the highest reported in the literature. Recovery of potency required 9 to 12 months. They hypothesized that the excellent outcome in the study patients were related to the preservation of additional erectile nerves in the prostatic fascia. Nevertheless, they stated that they have not performed microdissection studies that trace accessory nerve channels to the corpora cavernosa. Therefore, it would equally be possible that the enhanced erectile function was the result of decreased traction or thermal injury to the nerves because the plane of dissection was far away from the putative NVBs. They proposed a third possibility of preservation of the prostatic fascia maintaining additional blood supply to the cavernous tissue, allowing the production of more endothelial nitric oxide, which is the factor responsible for the maintenance of penile erection. However, there were several caveats: This was a nonrandomized trial and patients in the study group were younger and had lower risk disease. While patients self-administered the mail-in questionnaire, data collection and analysis were done by individuals directly involved with surgical treatment. The investigators offer the fascia-sparing technique to men with low-risk disease (PSA < 10 ng/mL, clinical stage T1c, and Gleason sum 6 or less).

18.2.5. University of California, Irvine, Clipless Athermal Approach

In an effort to protect neural tissue from both thermal damage from energy sources and mechanical trauma from clipping, two centers reported using vascular clamps and suture ligation for controlling the prostatic pedicle. In the robotic technique of investigators from the University of California, Irvine, after mobilizing the prostate off the rectum, prostatic vascular pedicles are delineated and thinned. Laparoscopic 30-mm bulldog clamps are placed on the vascular pedicles at least 1 cm from the prostate.[12] From this point, only cold scissors are used to divide the vascular pedicles very close to the prostate. The lateral fascia is incised along the prostate, and the NVB gently dissected off the prostatic capsule. After complete mobilization of the NVB down to the urethra, the authors initially applied Floseal (Baxter, Deerfied, IL) along the entire length of the NVB. Floseal was then covered with a dry 1 × 5 cm sheet of Gelfoam (Pfizer, Inc, New York, NY) to act as a protective cover to keep the Floseal particles in place. In a more recent report, they reported that hemostatic agents failed to control bleeding acutely approximately 20% of the time, and thus they abondoned their use in favor of time-proven suture ligature.[3] The investigators now control the vessels in the vascular pedicles using a running 3-0 polyglycolic acid suture ligature. Prior to removing the bulldog clamp, two throws are placed through the vascular pedicle. The bulldog clamp is then removed, and the suture is used to display the remaining vessels such that precise needle placement is facilitated to avoid injury to the NVB. If pulsatile bleeding is seen along the NVB, precise ligature of the bleeding site is performed with a 4-0 suture on an RB needle. The authors state that suturing is very much facilitated by the 10× to 12× magnification and precise suturing skills of the robot. They reported nearly a fivefold increase in return of early sexual function with this cautery-free technique compared to the group they operated with bipolar cautery when dividing the vascular pedicle (43% vs. 8.3%). They also attempted to assess partial recovery. Cautery-free group reported 18% zero fullness at three months, whereas this rate was nearly 70% in the bipolar energy group. In the University of California, Irvine, experience, men were selected for excision of one or both NVBs if the patient had extensive involvement noted on biopsy cores (more than 50% by volume estimate and/or Gleason score greater than 4 + 3), obvious palpable disease (with biopsy confirmation), inadequate sexual function (SHIM score < 10), or patient preference.

18.2.6. Cleveland Clinic: Clamp and Suture Technique with Ultrasound Guidance

Utilization of vascular clamps for controlling the vascular pedicle during conventional laparoscopic radical prostatectomy was reported from the Cleveland Clinic.[13] Once the pedicle is dissected out, a 25-mm straight atraumatic bulldog clamp (CEV565, MicroFrance Medtronic Xomed, Jacksonville, FL) is placed obliquely at a 45° angle across the pedicle of the prostate close to the bladder neck, at some distance from the posterolateral edge of the prostate (Figure 18.1). Using cold scissors, the lateral pedicle is divided, leaving an approximately 1 to 2 mm edge of pedicle tissue extending beyond the jaws of the bulldog clamp. Importantly, TRUS imaging provides real-time guidance along the posterolateral edge of the prostate, minimizing inadvertent compromise of the prostatic capsule. Once the last few remaining attachments of the lateral pedicle are divided, the NVB becomes evident. At this point, the NVB is released in an antegrade manner along the convexity of the prostate toward the apex using a combination of both sharp and blunt dissection. Complete avoidance of thermal energy keeps the appearance and color of tissues unchanged, aiding in a more precise dissection in the correct plane. At this time, 4-0 polyglactin suture on an RB 1 needle cut to 6 to 8 cm is used to suture the transected lateral pedicle superficially (Figure 18.2). The bulldog clamp is removed next, and any bleeding vessels meticulously sutured for hemostasis. TRUS measurements are obtained both before and during the application of the bulldog clamp, and at prostatectomy completion. TRUS parameters evaluated include the dimensions of the NVB, number of visible vessels, and resistive index of arterial flow within the NVB[14].

When the investigators from the Cleveland Clinic initially used vascular clamps to control the pedicle, they extrapolated from their experience with hemostatic bioadhesives during laparoscopic partial nephrectomy, and evaluated the use of Floseal. However, parallel to the experience at the University of California, Irvine, Floseal could not achieve reliable hemostasis of bleeding vessels from the prostate pedicle and the NVB. Another concern brought up by the authors was about the healing process after topical application of bioadhesives, which might result in reactionary fibrosis, exuberant lymphocytic infiltrate, and an inflammatory response.[15] In this technique, one could question whether the bulldog clamp itself imposes mechanical trauma to the delicate fibers of the NVB. Nevertheless, the major structure controlled by the bulldog clamp is the lateral pedicle containing the distal branches of the inferior vesicle artery to the prostate base and bladder neck, and not the NVB.[13] TRUS demonstration of continued pulsatile blood flow within each NVB during active bulldog clamping is encouraging, suggesting that minimal occlusive pressure is imposed on the NVB. The investigators believe that lateral prostate pedicle is thicker in size than its underlying thinner NVB; therefore, placement of the bulldog clamp on the overlying bulkier prostate pedicle likely does not compress the underlying NVB. The resistive index of arterial flow within each NVB remains the same. Some bleeding is reported to occur from the transected blood vessels of the lateral pedicle, indicative of the relatively gentle occlusive force of the vascular clamps. Thus, direct trauma to the cavernous nerve fibers is unlikely. The potency data are still awaited.

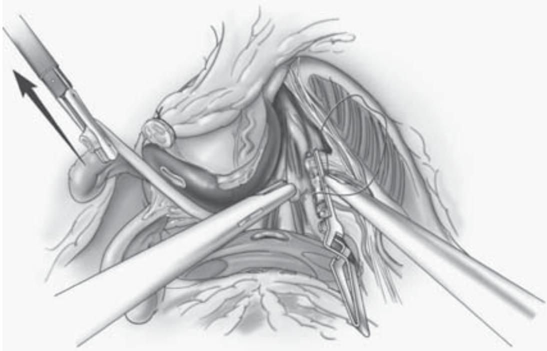

Figure 18.2. Meticulous superficial suturing (4-0 polyglactin) of transected lateral pedicle. (Reprinted with kind permission from Inderbir S and Gill MD, Cleveland Clinic Foundation, Cleveland, OH.)

18.2.7. Sural Nerve Grafting

Restoration of erectile function is quantitively related to the preservation of autonomic innervation.[16] In men with extensive bilateral high-grade cancer who are at risk for extracapsular extension, it is quite reasonable to excise one or both NVBs in an effort to avoid positive margins. When the resection of both NVBs is required, the recovery of spontaneous erections adequate for intercourse is the exception. Interposition sural nerve grafting during radical prostatectomy provides a potential pathway to restore autonomic innervation and offers men the increased possibility of recovery of spontaneous erections.[17] The sural nerve has traditionally been used for nerve reconstruction, and has been used clinically with brachial plexus, fascial nerve, and peripheral nerve injuries.[18] Kim and Scardino reported that the use of this nerve during open radical prostatectomy was feasible and effective.[19,20] One study reported overall return of sexual activity in 75% of men (including medically assisted).[21] This technique was initially replicated with the laparoscopic approach by Turk and colleagues.[18] They applied the technique in 15 men and stated that the magnified optics, bloodless surgical field, and improved instrumentation create an optimal environment for sural nerve grafting to the cut ends of the NVBs. During the laparoscopic approach, the nerve grafts were placed prior to constructing the anastomosis. This provided an optimal view of all structures under direct vision during the entire anastomotic procedure. During open surgery, however, it is recommended that the sutures be placed before, but tied after nerve graft replacement.[22] Porpoglia and colleagues confirmed the feasibility and safety of laparoscopic sural nerve grafting. Although they reported encouraging improvement in Index of Erectile Function scores at 3 to 18 months, they failed to show a significant improvement with nerve grafting versus no grafting.[23] They speculated that the magnification of the operative field is better with the microsurgical technique, and thus anastomosis made by the laparoscopic technique might be inadequate. Robot-assisted laparoscopic sural nerve grafting during radical prostatectomy was reported by Kaouk and associates in three patients.[24] Two patients had bilateral resection of the NVBs and one patient had a unilateral resection with grafting. Prostatectomy was performed robotically in one case and in a standard laparoscopic fashion in the two remaining cases. During a mean follow-up of 4.3 months, the patient with unilateral nerve preservation was potent without any medication and one patient with bilateral nerve grafts reported penile engorgement with sildenafil that was not sufficient for penetration.

18.2.8. The Ohio State Technique: Athermal Early Retrograde NVB Release During Antegrade Prostatectomy

Dr. Patel has recently described a unique robot assisted laparoscopic approach to nerve sparing, modeled upon the fusion of traditional open and standard laparoscopic surgical technique. While the majority of the procedure is performed in the standard antegrade laparoscpic manner, the nerve sparing is performed retrograde as in traditional open surgery from apex to base. The basic premise is that the NVB can best be identified and released at the apex of the prostate and delineated back to the pedicle avoiding the possibility of inadvertent damage while controlling the pedicle. A possibility that is present during the antegrade laparoscopic approach.

Once the seminal vesicles have been mobilized, the anterior and posterior layers of Denonvillier's fascia are separated to develop the posterior space. The prostate is then elevated to identify the lateral attachments. It is of great importance to fully dissect the posterior space and release the rectum from the posterior surface of the prostate as this improves the ability to rotate the prostate. Once this has been performed the nerve sparing can proceed. The technique involves incision of the periprostatic fascia at the level of the apex and midportion of the prostate. Gentle spreading of the tissue on the lateral aspect of the prostate will allow the prostatic capsule and the NVB to be identified. No thermal energy is used during dissection of the NVB or ligation of the pedicle. At the apex of the prostate a plane between the NVB and prostate capsule can be identified and separated. The NVB is then released in a retrograde manner towards the prostatic pedicle. The NVB is stabilized with the Maryland dissector and the prostate is gently stroked away using the scissors. The plane between the NVB sheath and the prostate capsule is relatively avascular consisting off only small tributary vessels, therefore no energy or clipping is required close to the path of the NVB. As the dissection proceeds in a retrograde fashion the NVB can clearly be seen being released off of the prostate. The prostate pedicle can then be thinned out with sharp dissection and the path of the NVB clearly delineated at this level. The clear definition of the anatomy allows the placement of two clips on the pedicle away from the NVB and sharp incision to release the prostate completely. This identical procedure can be performed bilaterally, completely releasing the prostate. This technique is illustrated **in Appendix A**.

18.3. Conclusion

Radical prostatectomy remains the most proven effective treatment for clinically localized carcinoma of the prostate. Cancer cure, rapid recovery of complete urinary continence, and preservation of sexual function are desirable in the contemporary surgical treatment of the young potent male with prostate cancer. Erectile dysfunction is the most frequent long-term quality-of-life compromise faced by men undergoing treatment for carcinoma of the prostate. Thus, improvements in technique that hold promise for better potency preservation would represent a significant advance in the field of prostate cancer surgery. Robot-assisted laparoscopic surgery has various advantages. Three-dimensional and magnified vision, visual capability provided minimal blood loss, and intimate and precise camera positioning at the area of interest allow for superior view of the prostate capsule and the NVBs. Intuitive instrument handling and machinelike precision with seven degrees of freedom of the wristed instruments allow for easier and probably more precise dissection compared to pure laparoscopy. If these technical advantages translate to higher quality surgery with superior outcomes, robotic radical prostatectomy appears to have a potential to improve erectile function preservation after prostate cancer surgery.

Most described techniques for robotic radical prostatectomy use an antegrade approach as opposed to a retrograde dissection most commonly used with open surgery. The principles of anatomic dissection for nerve sparing are the same regardless of surgical approach. Injury to the nerves can occur by inadvertent incision and/or excision, incorporation of the nerves in hemostatic sutures or clips, excessive traction, and thermal energy. Procedures that minimize trauma to the periprostatic tissue and allow precise dissection along the prostatic capsule have the capability of providing improved functional outcomes for potency. There is considerable potential for the magnified view of the operative field provided by laparoscopy/robotic surgery to provide more accurate and less traumatic dissection of the NVBs. There is substantial evidence to support that preservation of the neural network within the anterior prostatic fascia may help in preventing postoperative erectile dysfunction.

Techniques most commonly used for nerve-sparing robotic radical prostatectomy have been summarized in detail in this chapter. There is no published data to allow definitive conclusions about the relative merits of robotic-assisted laparoscopic radical prostatectomy compared with open radical prostatectomy in avoiding erectile dysfunction. Most intrainstitutional comparisons demonstrate better postoperative potency with the robotic approach, but there is still debate about whether results are superior to radical retropubic prostatectomy in the hands of a highly experienced surgeon.[25] Minimally invasive surgical approaches for radical prostatectomy likely assume an even greater, and most probably the leading role in the treatment of localized prostate cancer. Comparison of analysis of outcomes following robot-assisted laparoscopic and alternative surgical approaches will determine the ultimate role of this new surgical approach.

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19

Management of Postprostatectomy Erectile Dysfunction

Craig D. Zippe and Shikha Sharma

19.1. Introduction

The concept of early penile rehabilitation following radical prostatectomy started in the 1990s with the evolution of several dynamic themes regarding prostate cancer diagnosis and management. First, with the maturation of serum prostate-specific antigen (PSA) testing, the detection of lower volume cancers changed the surgical margin rate and the rate of biochemical cures rose substantially, to the 80% to 90% range. The majority of our newly diagnosed tumors were histologic Gleason score 6/7 cancers and were pathologically organ confined. Recent cancer statistics for the year 2006 report that 91% of new prostate cancer cases are expected to be diagnosed at local or regional stages with five-year cancer-specific survivals approaching 100%.[1] A second major theme of the 1990s was the substantial drop in patient age at diagnosis due to earlier screening with serum PSA testing and improved office-based ultrasound-guided biopsy techniques. In fact, the largest increase in prostate cancer incidence during the PSA era occurred in men under the age of 65. The Seattle-Puget Sound Surveillance, Epidemiology and End Results (SEER) cancer registry from 1995 to 1999 reported that 33% of all incident prostate cancer cases are now diagnosed in men under age 65[2–4] and this figure will invariably be higher in the subsequent five-year report.

This diagnostic shift towards earlier age and lower tumor volumes suggests that prostate cancer survivors will have longer life expectancies after diagnosis, regardless of treatment, and higher expectations on health-related quality of life issues — foremost, urinary continence and erectile function. Another theme of the 1990s was a re-examination of our potency rates following various treatments for erectile dysfunction (ED) after prostate cancer treatment. Younger prostate cancer patients now want information on both short- and long-term potency rates following prostate cancer treatments and the efficacy of the various treatment options in treating their erectile dysfunction. The demands of the younger patient for higher potency rates pushed many surgeons into using earlier intervention strategies to improve our potency rates following radical prostatectomy (RP). During 1990s, with many experienced retropubic surgeons focusing religiously on improving their nerve-sparing surgical technique, it became evident that the volume of surgeries (i.e., 1000 or more cases) may not be the answer to improving potency rates following RP. It was this realization or concession that technical improvements in nerve-sparing retropubic surgery could not be advanced to any great extent that motivated the prostate cancer community to consider the role of early penile rehabilitation.

19.2. Approaches to Radical Prostatectomy: Potency Rates

19.2.1. Retropubic Approach

When analyzing the reported potency rates following radical retropubic prostatectomy (RRP), we find the results from bilateral nerve-sparing

Table 19.1. Potency rates following bilateral nerve-sparing retropubic radical prostatectomy.

Reference	Mean age (years)	*n*	Mean follow-up (months)	Partial erections	Vaginal potency with or without adjuvant PDE-5 inhibitors
Quinlan (1991)[6]	>50	29	18	n/a	90%
	50–59	141	18	14%	82%
	60–69	112	18	21%	69%
	>70	9	18	22%	22%
Leandri (1992)[12]	68	106	6/12	38/15%	30/56%
Jonler (1994)[10]	64	93	22.5	38%	9%
Geary (1995)[11]	64	69	18	16%	32%
Talcott (1997)[9]	65	37	12	89%	11%
Walsh (2000)[7]	57	64	2/18	n/a	73/86%
Catalona (2004)[14]	>50	125	18	n/a	93%
	50–59	675	18	n/a	85%
	60–69	794	18	n/a	71%
	>70	176	18	n/a	52%

Abbreviation: n/a, not available.

procedures vary widely. Erectile function following retropubic prostatectomy in the hands of experienced surgeons (>1000 cases) at centers of excellence ranges between 40% to 86%.[5–9] However, the vast majority of urologists rarely report or experience potency rates higher than 40%, with the range being from 9% to 40%.[10–12] Table 19.1 lists the selected potency rates of various authors from major U.S. hospitals. Table 19.2 summarizes this author's personal potency rates from a period of 2003–2005. This was a consecutive series of bilateral nerve-sparing retropubic prostatectomies; all patients were less than 65 years old, with a minimum follow-up of 18 months, and a baseline score on the International Index for Erectile Function-5 questionnaire (IIEF-5) greater than 20. At 18 months, only 38% had natural spontaneous erections sufficient for vaginal intercourse, and the use of sildenafil citrate increased this percentage to 56%. Lower figures from the Cleveland Clinic retropubic prostatectomy database were quoted by Schover and colleagues in 2002, who analyzed 1207 patients with a mean follow-up of 4.3 years following surgery.[13] The natural potency rate at 48 months was 18%, which improved to 33% with oral 5-phosphodiesterase (PDE-5) inhibitors.

This series from the Cleveland Clinic included all surgeons performing radical prostatectomy from 1992–1999. These potency figures most likely reflects the academic norm from a large center of excellence and perhaps figures better than the community setting and puts an exclamation mark on the morbidity of a radical retropubic prostatectomy. While several prominent retropubic surgeons have set the gold standard for emulating potency rates with percentages in the high 60% to 90% range, these numbers are probably achieved only with a large volume of surgeries (>3000 cases) and a large volume of younger patients (<60 years old).[14] Unfortunately, in the years ahead, it will be very difficult for an individual surgeon to accrue this volume of cases with the competing influences of prostate brachytherapy and the more integrated external beam radiation techniques.

Table 19.2. Potency rates: personal and Cleveland Clinic Foundation series for bilateral nerve-sparing retropubic prostatectomy.

Follow-up	Vaginal potency	Adjuvant PDE-5 inhibitors
3 months	0%	0%
6 months	18%	28%
12 months	33%	44%
18 months	38%	56%
48 months (CCF)[a]	18%	33%

[a] Published 2002 review by Schover and colleagues of open radical prostatectomies performed by multiple Cleveland Clinic surgeons between 1992 and 1999. This review includes the current author's series of prostatectomies (100 consecutive surgeries; 2003–2005; preoperative IIEF-5 score > 20; age < 65 years).

19.2.2. Perineal Approach

In one of the earliest reports, in 1991, Frazier and colleagues, from Duke University, reported on 51 patients who underwent radical perineal prostatectomy (RPP).[15] Seventeen of 22 patients (77.3%) in the radical perineal group who underwent bilateral nerve sparing were reported to be potent one year after surgery. This study from 1991 did not define potency as vaginal intercourse and lacked a validated questionnaire.

In 1988, Weldon and Tavel first described the technique of nerve-sparing RPP.[16] However, it was not until 1997 that Weldon and associates published potency rates in a subset of only 50 patients (mean age, 67 years) who had excellent preoperative potency and underwent nerve-sparing procedures (22 bilateral, 28 unilateral). Weldon and colleagues reported an overall potency rate of 70% at 24 months, with potency returning in 24% at 6 months, 50% at 12 months, 64% by 18 months, and 70% at 24 months. Unilateral nerve sparing preserved potency in 19 of 28 men (68%). Age was found to be significant variable in this group of patients. Potency returned in all 4 men (100%) less than age 50 years, 12 of the 17 (71%) ages 50 to 59, 17 of the 22 (77%) ages 60 to 69, and 2 of the 7 (29%) ages 70 or older.[17] However, this study used physician-reported, rather than patient-reported outcomes, and did not use a validated questionnaire.

In 2001, Ruiz-Deya and associates stated their outcome on 250 consecutive patients (mean age, 63 years) who underwent outpatient RPP from 1992 to 1997. Mean hospital stay was 23 hours. Patients were assessed by a validated questionnaire — the Functional Assessment of Cancer Therapy-Prostate Instrument quality of life. Bilateral or unilateral nerve-sparing surgery was only performed in 54 of the 250 patients. Follow-up results at 18 months revealed that 28/54 (56%) patients had unassisted potency and satisfactory sexual function, although 8 of these patients were not satisfied with the quality of the erection and sought erectaids.[18]

In 2003, Harris and coworkers reported outcome data on 508 radical perineal prostatectomies (mean age, 65.8 years) performed by single surgeon over the past 8.5 years. Unfortunately, until recently, the technique of performing bilateral nerve sparing in the perineal approach was not well understood. In Harris' series, only 12 bilateral nerve-sparing procedures were performed since July 2001, with 10 patients (83%) recovering spontaneous erections (no reports of vaginal potency) within six months. In the unilateral nerve-sparing group, 34/46 (74%) reported spontaneous erections in a follow-up period ranging from two months to two years.[19] The limitations of this study were the short follow-up period in the bilateral nerve-sparing group, the lack of standardized questionnaires, and the definition of potency that was not defined as vaginal intercourse.

Table 19.3 summarizes the vast majority of literature reports on erectile function following RPP. There is a paucity of reports with no current contemporary series in our younger patients where bilateral nerve-sparing procedures are principally performed.

19.2.3. Laparoscopic Approach

Laparoscopic radical prostatectomy (LRP) emerged as a minimally invasive surgical technique in 2000 as an alternative to open retropubic prostatectomy.[21–23] A major impetus for the

Table 19.3. Potency rates following bilateral nerve-sparing perineal radical prostatectomy.

Reference	Mean age (years)	*n*	Mean follow-up (months)	Partial erections	Vaginal potency with or without adjuvant PDE-5 inhibitors
Frazier (1992)[15]	65	22	12	n/a	78%
Lerner (1994)[20]	63	27	23	30%	22%
Weldon (1997)[17]	67	22	12/24	n/a	50%–70%
Ruiz-Deya (2001)[18]	62.9	54	18	n/a	41%
Harris (2003)[19]	65.8	12	6	83%	25%

Abbreviation: n/a, not available.

development of minimally invasive techniques for prostate cancer was to minimize patient morbidity, length of stay, and postoperative pain. Initially, due to the lengthy learning curve, the development of nerve-sparing techniques was not a priority and the percentage of patients receiving bilateral nerve-sparing procedures was less than expected.

In 2000, Guillonneau and colleagues first reported the potency outcomes following LRP. Of the 120 laparoscopic procedures performed between February 1998 and May 1999, only 20 were bilateral nerve sparing. Of these 20, 9 (45%) reported spontaneous erections, including 1 with rigidity sufficient for sexual intercourse 12 months following surgery.[24] In a recent updated study with 550 LRP procedures, they report only 47 patients underwent bilateral nerve-sparing procedures. Of this 47, 31 (66%) patients experienced intercourse with/without adjuvant sildenafil citrate and 85% recovered spontaneous erections. Interestingly, the period of time for the recovery of vaginal intercourse ranged from three weeks to four months.[25] These figures at three weeks to four months are just too good to go unconfirmed, and suggest that the laparoscopic approach may significantly shorten the period of neuropraxia. Table 19.4 reviews the potency rates following bilateral nerve-sparing LRP, with reports ranging from 14% to 81%.[25–31]

In 2003, Anastasiadis and associates prospectively evaluated 300 patients who underwent radical prostatectomy (70 retropubic, 230 laparoscopic).[26] The mean age of the retropubic group was 64.8 years; in the laparoscopic group, 64.1 years; 96.6% of the patients were potent preoperatively. This group at one year follow-up reported an overall potency rates of 30% via the retropubic approach and 41% via the laparoscopic approach ($p > 0.05$). With preservation of one neurovascular bundle, the potency rates were 27% (retropubic) and 46% (laparoscopic). After bilateral nerve-sparing procedures, the potency rate increased to 44% (retropubic) and 53% (laparoscopic; $p > 0.05$). For patients younger than 60 years with bilateral neurovascular bundle preservation, the potency rates were 72% (retropubic) and 81% (laparoscopic) one year after surgery ($p > 0.05$).[26]

In 2003, Roumeguere and colleagues reported no significant difference in potency rates following RRP and LRP. They followed 77 patients (mean age, 63.9 ± 5.5 years) following RRP and 85 patients (mean age, 62.5 ± 6.0 years) following LRP prospectively at 1, 3, 6, and 12 months. Erectile dysfunction was assessed using Q3 and Q4 of International Index of Erectile Function questionnaire. At one-year follow-up, 54.5% (18/33) from the bilateral nerve-sparing retropubic group had erections sufficient for vaginal potency versus 65.3% (17/26) from the bilateral nerve-sparing laparoscopic group. Fu rthermore, 14 of these 17 patients (82%) that underwent bilateral nerve-sparing laparoscopic surgery were able to have vaginal penetration without an oral medication, while only 8 out of 18 (44%) in the open group could achieve vaginal potency without an oral PDE-5 inhibitor.[27]

In 2005, Rozet and associates reported potency rates following extraperitoneal LRP. Of the 599 extraperitoneal surgeries (mean age, 62 years) performed between February 2002 to March

Table 19.4. Potency rates following bilateral nerve-sparing laparoscopic radical prostatectomy.

Reference	Mean age (years)	*n*	Mean follow-up (months)	Partial erections	Vaginal potency rate with or without adjuvant PDE-5 inhibitors
Guillonneau (2002)[25]	<70	47	4	85%	66%
Hara (2002)[30]	<70	7	3	71%	14%
Roumegure (2003)[27]	62.5	26	12	n/a	65%
Anastasiadis (2003)[26]	<60	77	12	n/a	81%
Rozet (2005)[28]	62	89	6	64%	43%
Rassweiler (2006)[29]	<55	n/a	12	n/a	78%
Curto (2006)[31]	62	137	12	35%	59%

Abbreviation: n/a, not available.

2004, 139 (23.2%) underwent bilateral nerve sparing. With a mean follow up of 6 months in 89 bilateral nerve-sparing patients, with a preoperative IIEF-5 [Sexual Health Inventory for Men (SHIM)] grade of more than 20, the rate of partial erections and vaginal potency was 64% and 43%, respectively.[28]

In 2006, Curto and colleagues described their nerve-sparing technique using an intrafascial approach during laparoscopic nerve sparing. The intrafascial approach includes: not opening the reflection of the endopelvic fascia, preservation of bladder neck, no cautery, reflection of the periprostatic fascia, and control of Santorini plexus (or dorsal vein) at the end of the procedure after section of the urethra. This approach was performed in 425 patients with median age of 62 years. They reported postoperative potency rates of 30% (42/140) at 3 months, 43% (50/117) at 6 months, and 58.5% (80/137) at 12 months. Erections not sufficient for sexual intercourse were observed in 43 patients (31%) at 3 months, in 52 patients (44.5%) at 6 months, and in 48 patients (35%) at one year.[31]

Table 19.4 lists the reported potency rates following LRP. The conclusion from the laparoscopic literature is that the potency rates are equivalent, if not better, that those reported from open retropubic series.[26,27,32] The limitations of this approach appear to be the lengthy learning curve and the large number of cases required before the surgeon is comfortable doing bilateral nerve sparing. While this is a minimally invasive procedure, it is still apparent that the laparoscopic nerve-sparing technique causes enough neurovascular injury and damage to produce the routine neuropraxia that we commonly see.

19.2.4. Robotic-Assisted Laparoscopic Approach

Menon and associates pioneered and popularized the da Vinci® robot (Intuitive Surgical, Inc., Sunnyvale, CA), demonstrating that this technology could overcome the counterintuitive pitfalls of standard laparoscopic surgery.[33] Robotic assistance provided by the da Vinci® surgical system offers the open surgeon sophisticated tools with which to perform complex laparoscopic surgery. It provides three-dimensional (3D) visualization, 10- to 15-fold magnification, wristed instrumentation, intuitive finger-controlled movements, and a comfortable seated position for the surgeon, all of which makes for an advanced ergonomic operation. With 3D magnification and nonexistent blood loss, it has never been easy to identify and fine-tune the neurovascular dissection (Figure 19.1).

Early potency rates from robotic-assisted laparoscopic prostatectomy (RALP) are impressive (Table 19.5.[34,35,37–44] In 2003, Bentas and colleagues described their early outcomes at one year with RALP in 37 patients with mean age of 61.3 years. Of 37 potent patients before surgery, 8 (22%) had regained sexual activity, although all required adjuvant medical therapy.[34] In the same year (2003), Menon and associates from the Vattikuti Institute reported their interim results with RALP in 200 patients (mean age, 59.9 years). Patients were followed at baseline and at 1, 3, 6, 12 and 18 months after surgery with validated questionnaires [Expanded Prostate Cancer Index Composite (EPIC)]. They reported that at six months 82% of the men less than 60 years of age and 75% of men more than 60 years of age had return of partial erections and 64% and 38%, respectively, had erection sufficient for vaginal intercourse.[35] This group, which also had a large experience with open retropubic surgery, observed that patients were regaining potency

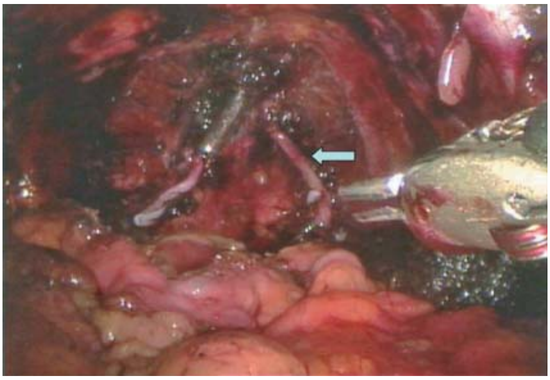

Figure 19.1. Intraoperative photograph during robotic-assisted nerve-sparing radical prostatectomy. Three-dimensional view 10 to 15 times magnification allows unparalleled exposure of the neurovascular bundle. (Reprinted courtesy of the Cleveland Clinic, Cleveland, OH.)

Table 19.5. Potency rates following bilateral nerve-sparing robotic-assisted radical prostatectomy.

Reference	Mean age (years)	*n*	Mean follow-up (months)	Partial erections	Vaginal potency rate with or without adjuvant PDE-5 inhibitors
Menon (2005)[39]	57.4	58	12	17/51%[a]	74%/97%[a]
Ahlering (2005)[42]	<66	23	3	n/a	43%
Tewari (2005)[44]	60	n/a	6	n/a	78%
Joseph (2006)[43]	60	129	6	n/a	80%
Kaul (2006)[40]	57	102	12	71%	96%[a]

Abbreviation: n/a, not available.

[a] Veil of Aphrodite nerve sparing surgery (prostatic fascia sparing).

faster with RALP and felt that the neurovascular bundles were protected better with the 3D vision provided by the robotic technology.[35,36] In the same year, this group compared their outcomes using the Vattikuti Institute Prostatectomy (VIP) technique (RALP) and RRP in 300 patients (100 RRP, 200 VIP). The mean age of patients who have undergone VIP and RRP was 59.9 years and 63.1 years, respectively. Sexual function was evaluated in all patients with a baseline (preoperative) IIEF–5 score of more than 18 who had undergone bilateral nerve-sparing procedures. It was reported that after VIP, patients had earlier return of erections than after RRP (180 vs. 440 days, $p < 0.5$). The median return to intercourse was 340 days after VIP, but after RRP, 50% of the patients had not yet resumed intercourse at 700 days ($p < 0.05$).[37] This early return of sexual function was attributed to better visualization and a better anatomical dissection, which resulted from reduced blood loss and 3D vision.[36]

In 2005, Kaul and colleagues from the Vattikuti Institute described the feasibility and efficacy of preserving the prostatic fascia (veil of Aphrodite) during RALP.[38] This fascia anatomically is composed of numerous smaller neurovascular components which theoretically can influence the return of potency postoperatively. Kaul and colleagues reported potency rates in patients who have undergone conventional bilateral nerve-sparing RALP ($n = 23$; mean age, 60.5 years) versus those who have undergone the more skeletonized procedure with prostatic fascia preservation or the veil of Aphrodite ($n = 35$; mean age, 57.4 years). All these 58 patients had a baseline or preoperative IIEF-5 (SHIM) greater than 21 without PDE-5 inhibitors. At 12 months, 17 of 23 (74%) of the conventional nerve-sparing RALP and 34 of 35 study (97%) of the veil technique achieved erections strong enough for intercourse. Four (17%) of the conventional RALP and 18 (51%) of the veil patients achieved normal erections (IIEF >21) without medication.[39]

In 2006, Kaul and associates updated their results using the veil technique of prostatic fascia sparing at one year in 154 patients (mean age, 57.4 years). In this series, 102 men with normal sexual function before surgery (IIEF-5 > 21) were included in analysis. At one year, 96% of the men reported having vaginal intercourse and 71% recovered normal erectile function. The mean IIEF-5 (SHIM) scores before and after surgeries were reported as 24.3 and 20.6, respectively, with a median IIEF-5 score of 22 postsurgery.[40]

In 2005, Chien and associates from the University of Chicago reported potency rates following RALP series using modified clipless antegrade nerve preservation. Fifty-six patients (mean age, 58.8 years) were prospectively followed after nerve-sparing procedures. The overall return to baseline sexual function was 47%, 54%, 66%, and 69% at 1, 3, 6, and 12 months, respectively, postoperatively. No statistically significant difference was found between unilateral or bilateral nerve-sparing groups.[41] In 2005, Ahlering and colleagues also reported on short-term potency outcomes with a cautery-free technique (CFT) to preserve the neurovascular bundles during RALP. Twenty-three patients, younger than 66 years of age with IIEF-5 (SHIM) score of 22 to 25, underwent cautery-free dissections and were prospectively followed. At three months, 43% of the patients in the cautery-free group had erections sufficient for vaginal penetration versus 9% in the bipolar cautery group.[42] This is a very short interval to report potency outcomes, so long-term follow-up is necessary.

In 2006, Joseph and associates evaluated their experience on 325 patients (mean age, 60.0 ± 6.4 years) who underwent da Vinci® robot–assisted extraperitoneal LRP. Erectile function was assessed using the IIEF-5 (SHIM) validated questionnaire in 150 patients. All patients used oral PDE-5 inhibitors for at least one month postoperatively. Looking specifically at the bilateral nerve-sparing group, at a mean follow-up of six months, 104/129 (80%) had IIEF-5 score greater than 16. In 68/104 (65%) of the patients, the IIEF-5 score ranged from 22 to 25; in 36/104 (37%), the IIEF-5 range was 16 to 21.[43] These results and those from the Vattikuti Institute are landmark contributions to literature on potency following RALP. The impact of using early PDE-5 inhibitors remains to be seen, but this adjuvant strategy may have contributed to these excellent outcomes.

Table 19.5 lists the reported potency rates following RALP. It would appear that potency rates following robotic-assisted laparoscopic radical surgery are generally much better than we had previously observed with open perineal or open RRP. While it may be argued that the potency rates from experienced laparoscopic surgeons are similar, the learning curve for such excellent potency rates following laparoscopic prostatectomy is quite long and tedious. The robotic approach appears to produce excellent potency rates with a much shorter learning curve. RALP may truly be the first major surgical advancement in the last 10 to 15 years that can improve potency rates and be universally performed. Having stated that, even in most experienced robotic hands, there still lies at least a 25% to 30% problem with erectile dysfunction. Consequently, even if 100% of our patients are having RALP in 2010 with a mean age of 55, we know at least one quarter to one third of our patients are ultimately going to need some form of sexual rehabilitation for long-term potency.

19.3. Concept of Early Penile Intervention

To understand the potential advantage of early intervention, we have summarized the literature on the reported efficacy of delayed treatments of erectile dysfunction following radical prostatectomy. Table 19.6 lists the efficacy and discontinuation rates of our various preoral treatments for erectile dysfunction following radical prostatectomy.[45] What is apparent is that our known treatments for ED do not have long-term durability, whether treatment is with intracavernosal injections (IC), vacuum constriction devices (VCD), intraurethral alprostadil [medicated urethral system for erection (MUSE)], or oral PDE-5 inhibitors. Patients have very high noncompliance rate with these treatments at one year and there is a paucity (if any) of data on five-year outcomes. Thus, with a younger male population with 10 to 15 years of sexual longevity, it is apparent that we do not have a durable and permanent solution for treating erectile dysfunction following radical prostatectomy.

Currently, the best treatment is to continue to perform and perfect a good bilateral nerve-sparing technique. It is this outcome measure that motivates our current enthusiasm for robotic radical prostatectomy because early reports on potency are significantly improved over previous reports from the other surgical approaches. The robotic nerve-sparing technique with the aid of 3D vision may be the most significant advance in the last decade in improving the short- and

Table 19.6. Efficacy and discontinuation rates of nonoral treatments for erectile dysfunction following radical prostatectomy: Cleveland Clinic Foundation data.[45]

Options	*n*	Presurgery vaginal potency (%)	Postsurgery vaginal potency (%)	With treatment vaginal potency (%)	Discontinuation rate following one year of use (%)
VCD	74	100	4.5	55	45
ICI	98	100	0	68	40
MUSE	27	100	0	32	74

Abbreviations: ICI, intracavernosal penile injections; MUSE, medicated urethral system for erection; VCD, vacuum constriction device.

long-term potency rates of younger patients. Nonetheless, even with the robotic technique, the sexual recovery of the patient is not perfect by any means. We still observe a significant period of neuropraxia in the first year and the one-year IIEF-5 scores postsurgery are usually lower that the baseline IIEF-5 scores, indicating some degree of nerve damage from the procedure. The role of early penile rehabilitation is apparent even if robotic approach evolves into the gold standard for performing nerve-sparing radical prostatectomy.

19.4. Pathophysiology of Nerve Injury: Historical Evidence

In 1982, Goldstein and colleagues first reported the role of the cavernosal smooth muscle in the normal erection.[46] Since then several authors demonstrated that normal smooth muscle content and function are essential in initiation and maintenance of the erection. The integrity and function of any smooth muscle is dependent upon tissue oxygenation. This phenomenon has been well established in cardiac myocytes. Similarly, the cavernosal smooth muscle function has been reported to be dependent on the tissue oxygenation. Historically, collagen accumulation (fibrosis) has been reported as the most probable cause of erectile dysfunction in patients with penile arterial insufficiency.[47–49] However, the exact mechanism of collagen accumulation in patients with penile hypoxia has not been established. In 1995, Moreland and colleagues reported that penile hypoxia induces transforming growth factor beta 1 (TGF-β_1) in the culture of cavernosal smooth muscle, which was implicated in the collagen deposition.[50] They also reported that prostaglandin E1 (PGE1) added to the cavernosal culture suppressed the TGF-β_1–induced collagen synthesis. In 1996, Daley and coworkers reported that the production of PGE1 in the cavernosal muscle, which suppress the TGF-β_1–induced collagen accumulation, was also oxygen dependent.[51,52] These initial reports have shown that penile hypoxia is the key factor in collagen deposition in hypoxic cavernosal muscle and PGE1 reduced the expression of TGF-$\beta_{1.}$ These research studies opened a new era of interest in the field of pharmacological prevention of erectile dysfunction following radical prostatectomy.

Nocturnal erections have been implicated in preserving normal erectile function by providing regular tissue oxygenation.[53] The lack of any erections during the period of neuropraxia has been implicated to produce persistent penile hypoxia. The hypoxia in consistently flaccid penis may induce fibrosis. Recently, Leungwattanakij and colleagues reported that three months after cavernous nerve damage in the rat model, the penile tissue biopsy revealed significant over expression of TGF-β_1 and collagen.[54] Similarly, in 2003, User and colleagues demonstrated significant apoptosis in the cavernosal smooth muscle and a high proportion of trabecular smooth muscle had been replaced by collagen.[55] The consequence of cavernosal apoptosis and collagen deposition leads to veno-occulsive disease. It also causes penile shortening both in length and girth because of scar tissue. Penile scarring, with its subsequent decreased penile length and girth, produces an end organ that yields a much lower response rate to all erectile dysfunction treatments.

Similarly, in human models, Iacono and coworkers from Italy recently studied the changes in penile biopsy before and after radical prostatectomy (2 months and 12 months). They reported a significant decrease in the elastic fibers and smooth muscle content and a significant increase in the collagen content in the postoperative biopsies compared to the biopsy before surgery.[56] This smooth muscle fibrosis has been implicated in reduction of penile length that occurs in significant proportion of men following radical prostatectomy. These studies have further confirmed that neuropraxia from transient cavernous nerve damage plays a central role in cavernosal fibrosis.

Progressive cavernosal fibrosis produced due to persistent penile hypoxia has been shown to produce veno-occlusive dysfunction. In 2002, Mulhall and colleagues reported that the incidence of venous leak increases with the postoperative time interval. They showed that the incidence of postoperative venous leak was 14% at 4 months, which increased to 35% between 9 and 12 months.[57] Similarly, in 1997, Montorsi and associates reported that the incidence of venous leak was much higher in control group (no treatment) compared to the treatment group (alprostadil injections three times/week): 53% versus 17%. These two studies revealed that postoperative venous leak was proportional to the time interval from the surgery and early treatment could result in a considerable decrease in venous leak.[58] It is evident from the literature that erectile dysfunction after radical prostatectomy is multifactorial in etiology. Penile hypoxia has been one of the most important precipitating factors in the formation of cavernosal fibrosis. The formation of cavernosal fibrosis with the subsequent venous leak has been implicated as one of the most important causes for the long-term erectile dysfunction after radical prostatectomy.

It is fair to say that in any one patient who undergoes radical prostatectomy, the insult can be primarily neurogenic, primarily vasculogenic, or mixed. It is a dynamic process from surgery to recovery. There is not one surgery where either nerves or blood flow is not comprised. This is evident by that the fact it takes 9 to 12 months for resolution of the associated neuropraxia.

19.5. Clinical Evidence (Studies) for Early Intervention

Unfortunately, the available clinical data comes from a number of small studies with relatively few subjects, and these studies are often nonrandomized. Overall, the circumferential or indirect evidence from multiple studies is that early intervention strategies can improve sexual activity, improve the return of natural spontaneous erections, and may improve, at least marginally (10%–25%), the return of natural erections sufficient for vaginal penetration or vaginal potency. Larger, randomized studies are needed to prove the last potential advantage, that early intervention improves the return of natural erections sufficient for vaginal potency. Currently, the potential clinical options for early intervention are listed in Table 19.7 and the current clinical data regarding these treatment options will be summarized below.

Table 19.7. Early treatment options for erectile dysfunction following radical prostatectomy.

- Pharmacological agents
  - Oral (daily/14–20 days/month)
    - a. PDE-5 inhibitors (sildenafil citrate, tadalafil, and vardenafil)
  - Intracavernosal injections (3/week)
    - a. PGE1 (alprostadil)
    - b. Low-dose Trimix (alprostadil, papaverine, phentoloamine)
    - c. Bimix (papaverine, phentoloamine)
  - Intraurethral alprostadil (MUSE; 3/week, 125 or 250 mcg)
- Nonpharmacological agents
  - Vacuum constriction device (daily for 5–10 min/without ring)
- Combination of above treatments

19.5.1. Early Use of Vacuum Constriction Devices

Currently, there is a considerable interest in early intervention protocols in the use of vacuum constriction devices (VCD) to encourage corporeal rehabilitation and prevention of post–radical prostatectomy veno-occlusive dysfunction, theoretically by increasing the frequency of tissue oxygenation. Early penile rehabilitation after radical prostatectomy may enhance earlier recovery of nocturnal erections by enhancing oxygenation of the corpora cavernosa and preventing formation of collagen and fibrosis, a cofactor in smooth muscle relaxation and erectile function. Clinically, this is evident by the preservation of penile length and girth that is seen with early use of the VCD following radical prostatectomy.

Our group several years ago completed a prospective, but nonrandomized study on the use of early VCD after retropubic prostatectomy at the Cleveland Clinic.[59] To our knowledge this is the only report in literature. This study included 109 patients who underwent radical prostatectomy between August 1999 and October 2001. Of the 109 patients, 74 (group 1) patients used early VCD daily for nine months and 35 were observed without any early maintenance erectogenic treatment (group 2). Patients in group 2 occasionally used oral PDE-5 inhibitors on an as-needed basis. Treatment efficacy was analyzed at baseline and subsequently by responses to the IIEF-5 or SHIM. Patient outcomes regarding the compliance, changes in the penile length and circumference, return of natural erection, and ability for vaginal

Table 19.8. Early use of vacuum contriction device following radical prostatectomy: results at nine months.

Variables	Early use of VCD ($n = 60$)	Observation (PDE-5 inhibitors as needed; $n = 22$)
Total IIEF-5 score	16 ± 7.3	12.06
Sexually active with/without VCD	60/60 (100%)	13/35 (37%)
Return of natural (partial) erections	19/60 (32%)	13/35 (37%)
Natural erection sufficient for vaginal potency (no VCD)	10/60 (17%)	4/35 (11%)

Abbreviation: VCD, vacuum contriction device.

intercourse were also assessed. With the minimum follow-up of nine months, 80% (60/74) in group 1 successfully used their VCD with a constriction ring for vaginal intercourse at a frequency of twice per week with an overall spousal satisfaction rate of 55% (33/60; Table 19.8). Nineteen of these 60 patients (32%) reported return of natural erections at nine months with 10/60 (17%) having erections sufficient for sexual intercourse. The abridged IIEF-5 score significantly increased after VCD use in both the nerve-sparing and non–nerve-sparing groups (Table 19.9). After a mean use of three months, 14/74 (18%) discontinued treatment. Overall in the early VCD group, 17% (10/60) had natural erections sufficient for sexual intercourse. In group 2, 37% (13/35) of patients regained spontaneous erections at a minimum follow-up of nine months after surgery. However, only 4/35 of these patients (11%) had erections sufficient for successful vaginal intercourse or potency, with the remaining patients (26%) seeking adjuvant treatment.

Table 19.9. Response to early vacuum constriction device in relation to nerve-sparing status: results at nine months.

Variable	Bilateral nerve sparing ($n = 31$)	Unilateral nerve sparing ($n = 22$)	Non–nerve sparing ($n = 21$)
Using VCD for sexual intercourse	25/31 (80.6%)	19/22 (86%)	16/21 (76%)
Spousal satisfaction	13/25 (52%)	11/19 (57%)	9/16 (57%)
Return of natural (partial) erections with VCD	9/31 (29%)	7/22 (32%)	3/21 (14%)
Natural erection sufficient for vaginal intercourse	5/31 (16%)	4/22 (18%)	1/21 (5%)

Abbreviation: VCD, vacuum constriction device.

Interestingly, when assessing the penile length and girth after surgery, in the 60 compliant VCD patients, only 14 (23%) reported a decrease in penile length and girth at nine months (range, four to eight months). In the noncompliant VCD patients, 12/14 (85%) complained about a decrease in penile length and girth. In the control group (no VCD), 22/35 (63%) reported decrease in penile length and circumference, demonstrating that routine early use of the VCD may prevent the decrease in penile length and circumference that routinely follows radical prostatectomy.

We concluded that early use of VCD following radical prostatectomy facilitated early sexual intercourse, early patient/spousal sexual satisfaction, potentially an earlier return of natural erections sufficient for vaginal potency, and preservation of penile length and girth. The other advantages of the VCD included a high patient compliance and affordability, because the VCD is covered by most insurance plans. However, the return of natural erections sufficient for vaginal potency was felt to be only marginally better between early VCD users and the control group (17% vs. 11%). While this pilot study needs to be replicated with a larger series and a standard early VCD protocol, this analysis prompted us to move on and look at a pharmacologic stimulus in the form of intraurethral alprostadil (PGE1, MUSE) in an attempt to improve the rate of natural vaginal potency.

19.5.2. Early Use of Intraurethral Alprostadil Medicated Urethral System for Erection

Our group recently completed a prospective nonrandomized study of 91 patients on the use of early MUSE after RRP at Cleveland Clinic Foundation.[60] We included total of 91 patients. Of the 91 patients, 56 received early MUSE and 35 (control group) did not receive any early erectogenic treatment. The control group occasionally used oral PDE-5 inhibitors on an as-needed basis. Patients in the early MUSE group received 125 micrograms (mcg) three times per week for the first six weeks. At six weeks, the MUSE dose was titrated to 250 mcg three times per week for four months. Patients who could not tolerate 250 mcg doses remained at 125 mcg for four months. Treatment efficacy was analyzed by the patient's response to IIEF-5 questionnaire.

In the MUSE group, 38/56 (68%) continued MUSE treatment. At nine months, 28/38 (74%) of the patients resumed sexual activity, 15/38 (40%) had natural erections sufficient for vaginal potency without MUSE, and 13/38 (34%) continue to use MUSE as an adjuvant treatment for successful vaginal potency. Overall, 40% (15/38) at nine months achieved natural erections sufficient for satisfactory sexual potency (Table 19.10). The MUSE discontinuation rate was 32% (18/56). Nine of the 18 (50%) discontinued because of inadequate erections, 5 (28%) due to loss of sexual interest, and 4 (22%) due to local pain/burning. In the control group, 13/35 (37%) regained spontaneous natural erections, but only 4/35 (11%) had natural erections sufficient for vaginal potency. Overall, only 11% (4/35) at six months achieved natural erections sufficient for satisfactory vaginal potency (Table 19.10).

We concluded that early MUSE therapy (at low doses of 125/250 mcg) increased the frequency of sexual activity, shortened the period of neuropraxia, increased the incidence of spontaneous erections, and increased the incidence of erections sufficient for vaginal potency. The disadvantages of early MUSE therapy included the high incidence of urethral irritation, the cost of the MUSE, and lack of insurance coverage.

Table 19.10. Early use of MUSE following radical prostatectomy: results at nine months.

Variables	Early use of MUSE ($n = 38$)	Observation (PDE-5 inhibitors as needed; $n = 35$)
Total IIEF-5 score	18.92	12.06
Sexually active with/without MUSE	28/38 (74%)	13/35 (37%)
Return of natural (partial) erections	21/38 (56%)	13/35 (37%)
Natural erections sufficient for vaginal intercourse (no erectaids)	15/38 (39%)	4/35 (11%)

19.5.3. Early Use of Oral Therapy with 5-Phosphodiesterase Inhibitors

There is a growing interest among the urologists regarding the early use of daily oral PDE-5 inhibitors. In 2004, Schwarz and colleagues analyzed cavernosal smooth muscle content in a postprostatectomy population. An Institutional Review Board (IRB) was obtained to perform baseline penile biopsy and a subsequent penile biopsy after six months of daily oral sildenafil citrate. A total 40 patients were included in the study and a first cavernosal biopsy was performed at the time of surgery. Patients were stratified to receive two different doses of sildenafil: group 1 ($n = 20$) received 50 mg per day and group 2 ($n = 20$) received 100 mg every other day. After six months follow-up, 11/20 in group 1 and 10/20 in group 2 underwent a second biopsy. At six months, group 2 (100 mg every other day) has significantly more smooth muscle content in the second biopsy (56.85%) compared to the first biopsy (42.82%; $p < 0.05$). In group 1 (50 mg daily dose), there was no significant difference observed in smooth muscle content in second biopsy (51.67%) compared to the first biopsy (51.52%; $p < 0.05$).[61] Thus, the 50-mg dose maintained the same level of smooth muscle content with no resulting atrophy. The study concluded that early use of sildenafil citrate (50 mg daily) following radical prostatectomy preserves the smooth muscle content and, at higher doses (100 mg q.o.d.), it increases the smooth muscle content.

Recently, the benefit of early sildenafil citrate has been reported by Padma-Nathan and colleagues, who conducted a randomized controlled study in 76 men (50 mg oral sildenafil daily $n = 23$; 100 mg oral sildenafil citrate daily, $n = 28$; placebo $= 25$) who underwent nerve-sparing radical prostatectomy with normal preoperative erectile function.[62] Sildenafil citrate was given for 36 weeks in the study group. Two months later, at 48 weeks (11 months) follow-up, 14 of 51 (27%) patients receiving sildenafil citrate had natural erections sufficient for intercourse

Table 19.11. Early use of sildenafil citrate following radical prostatectomy: IIEF-5 results at nine months.[62]

Variables	Group 1 (sildenafil citrate 50/100 mg for 36 weeks)	Observation (no sildenafil citrate)
n	51	25
Vaginal potency (%)	14 (27%)	1 (4%)
Positive NPT (%)*	10/35 (29%)	1/19 (5%)

Abbreviation: NPT, nocturnal penile erections.

compared to one of 25 (4%) in the placebo group (Table 19.11). This study revealed that oral daily sildenafil citrate increased the return of erections sevenfold compared with the placebo group and was well tolerated. In a subset of 54 patients from this study (35 sildenafil citrate group, 19 placebo group), measurement of nocturnal penile tumescence and evaluation of penile rigidity revealed that 29% (10/35) of the sildenafil citrate group demonstrated return of spontaneous erectile function compared to 5% (1/19) in the control group.[62] This study also demonstrated that tip rigidity of greater than 55% appears to be the most important parameter to discriminate between responders and nonresponders. This study has been criticized because the rate of vaginal potency in the placebo group was only 4%, which is low compared to the other reported series in the literature. While the study was randomized, the low rate of vaginal potency in the control group at 11 months softened the impact of this study. This interesting pilot study has stimulated several additional multicenter trials using sildenafil citrate, tadalafil, and vardenafil as potential early oral treatments.

In 2005, Gallo and colleagues from Italy evaluated the role vardenafil in the recovery of erectile function following pelvic urologic surgeries (RRP and cystectomy).[63] After six months of daily therapy, vardenafil therapy increased the mean IIEF-5 score to 12.9 points in the bilateral nerve-sparing group, to 8.0 in the unilateral nerve-sparing group, and to 11.3 points in the bilateral nerve-sparing radical cystectomy group. This study showed that vardenafil was well tolerated and potentially effective for recovery of erectile function following major pelvic urologic surgery. However, the lack of a contemporary control group may be a limiting factor in this study. A major problem in designing early intervention trials is having a compliant placebo group. Patients often do not want to be randomized. Thus, the best control group is often a contemporary series of patients who do not want any intervention or who discontinued an early treatment protocol due to side effects.

19.5.4. Early Use of Intracavernosal Penile Injections

In 1997, Montorsi and colleagues first demonstrated the advantage of penile injection therapy as an early intervention strategy in a randomized controlled study on patients after bilateral nerve-sparing radical prostatectomy. Patients were randomized to treatment (receiving intracavernosal alprostadil two to three times/week for 12 weeks, $n = 15$) and a control group (no treatment, $n = 15$). The mean intracavernosal PGE1 dose was 8 mcg (range, 4–12). After a minimum follow-up of six months, 67% (8/12) in the treatment group were reported to have spontaneous erections sufficient for satisfactory vaginal potency compared to the 20% (3/15) in control group. Penile Doppler studies revealed veno-occlusive dysfunction in only 17% (2/12) in the treatment group compared to 53% (8/15) in control group.[58] This paper was published in 1997, but the data was never confirmed. The concept of early PGE1 injections has been used anecdotally by various groups but has not become a mainstream option due to the lack of patient compliance secondary to penile pain. Adjusting the PGE1 dose postsurgically to avoid any penile discomfort has been a difficult problem and patients rarely forgive even a single episode of throbbing penile discomfort secondary to long-lasting prostaglandin effects.

Our group recently re-examined the role of intracavernosal injections immediately following radical prostatectomy. Our objective was to adjust the PGE1 dose to achieve 100% compliance. We felt injection therapy maybe the strongest pharmacologic stimulus to facilitate an earlier response to PDE-5 inhibitors. Our decision to begin an early injection program was based on a report from our group that 41% of long-term injection patients could be switched over to a PDE5 inhibitor.[64]

Table 19.12. Early use of combination therapy following radical prostatectomy: resulta at nine months.

Group	Total (*n*)	Initial injection dose (mcg)	Injection alone	PDE-5 + VCD	Partial erections (no erectaids)	Vaginal potency with or without PDE-5 inhibitors
PGE1[a] (mean, 4 mcg)	4	8	1	0	4	3
	6	4	3	2	6	1
	6	2	3	2	2	1
	2	1	2	0	1	0
Total	18		9	4	13	5
Trimix[b] (low dose)	4	30 U	2	1	2	1
Total (%)	22		11 (52)	5 (23)	15 (71)	6 (28)

[a] Intracavernosal alprostadil.

[b] Prostaglandin E1 (5.88 μg/mL), papaverine (17.65 mg/mL), and phentolamine (0.59 mg/mL).

Sexually active patients (*n* = 21/22, 96%). One patient on injections alone was not sexually active due to spousal illness.

In this report, we identified 49 patients using intracavernosal (IC) injections for more than one year. Of these 49 patients, 36 patients agreed to use sildenafil citrate orally (50–100 mg) for a minimum of four weeks/or eight attempts. Of the 36 patients, 41% (15/36) successfully switched to sildenafil citrate and discontinued IC injection. Fourteen of 36 (38%) found sildenafil citrate ineffective and remained on IC injection. Seven of 36 (19%) found sildenafil citrate alone to be suboptimal but continued to using it, enhancing the efficacy of IC injections alone.[64] Due to the potential of injection therapy to potentates the response of PDE-5 inhibitors, our group initiated an early injection program in combination with sildenafil citrate. Patients were asked to use IC injection two to three times per week and to take 50 mg sildenafil citrate on the remaining days. Prescriptions for 100 mg of sildenafil citrate were given and patients were asked to split the tablet.

This prospective study included 22 patients who underwent bilateral nerve-sparing RRP after October 2004 (Tables 19.12 and 19.13).[65,66] Sildenafil citrate dose of 50 mg/day was started at the time of hospital discharge. Of the 22 patients, 18 were started on intracavernosal alprostadil PGE1 (1–8 mcg) and four were started on low-dose Trimix (20–30 U) two to 3 times per week. These patients were followed at regular intervals (3, 6, 9, 12, and 18 months) with IIEF-5 questionnaires. We optimized the dose to achieve 95% compliance. This compliance rate was sustained to almost six months, then 10 of the 22 patients refused to do further injections. These 10 patients were amenable to switching to a VCD/ PDE-5 inhibitors. With a mean follow-up of nine months (6–18 months), 15/22 (71%) had return of spontaneous partial erections. Of the 22 patients, 21 (96%) are sexually active: 11/21 (52%) with injections and sildenafil citrate, 10/21 (46%) with VCD/sildenafil citrate. Overall 6/21 (28%) achieved vaginal potency with sildenafil citrate alone. At 6 months, penile Doppler studies revealed arterial insufficiency in 17/22 and venous insufficiency in only 1/22 of the patients. Baseline and 9-month IIEF-5 scores for the patients continuing injections or VCD were comparable: 22.3 ± 1.6 at baseline and 22.1 ± 0.3 at nine months. In the six patients using sildenafil citrate alone to achieve vaginal potency, the mean IIEF score was 11.5 ± 1.8.

Our early conclusion of this pilot study was combination therapy using intracavernosal

Table 19.13. Summary of sexual activity (vaginal potency) of patients following early combination therapy: results at nine months.

Sexual activity (vaginal potency)	21/22 (96%)[a]
Injections alone	10/21 (46%)
VCD and PDE-5 (sildenafil citrate)[a]	5/21 (23%)
PDE-5 (sildenafil citrate) alone	6/21 (28%)[b]

Abbreviations: PDE-5, 5-phosphodiesterase inhibitors; VCD, vacuum constriction device.

[a] One patient was not sexually active because of spousal ill health.

[b] Ten patients after 6 months declined further injections use. Five patients switched to VCD/PDE-5 inhibitors (sildenafil citrate) and another five were able to achieve vaginal potency with PDE-5 inhibitors alone.

injections and sildenafil citrate facilitated early sexual intercourse, patient satisfaction, earlier return of spontaneous erections, and potentially an earlier return of natural erections sufficient for vaginal potency. However, with nine months follow-up, results are still marginal in terms of vaginal potency. Whether longer follow-up will produce a higher incidence of vaginal potency over a contemporary control group remains unknown. What is apparent in conducting this study is that patient compliance, even in well-motivated patients with pain-free injections, is difficult to maintain after six months, with 50% of the patients refusing to continue injections.

A summary of early intervention therapies still leaves us uncertain as to what is the best form of early therapy (Table 19.14). We feel that use of oral sildenafil citrate/PDE-5 inhibitors alone is not strong enough in first 9 to 12 months to produce any erections sufficient for vaginal penetration. This delay will affects penile physiology and anatomy (length/girth) as well as changes in martial sexual relations and partner satisfaction. For this reason, we are committed to using adjunctive combination therapy, using oral PDE-5 inhibitors along with VCD, MUSE, or IC penile injections. Currently, the logistics of administering an early injection program in a normal office practice is sometimes prohibitive. Multiple visits are sometimes required to regulate the dose and the cost of the injections and needles can be an issue. These patients often need to be followed every one to two weeks to make sure the injections are done correctly, the proper dose is used, and to ensure there is no pain. The demands of an early injection program can be over run in office practice at times and may not be the right answer. Thus, in the present office urologic environment, an early VCD/PDE-5 inhibitor program may be the most effective, time-efficient, and cost-effective option. Most patients are compliant on a daily basis with a VCD. It allows immediate sexual intercourse and is reimbursed by insurance companies. As a combination therapy, patients do not have to pay monthly for two medications as exists with MUSE and IC injections.

Table 19.14. Summary of early intervention therapies following radical prostatectomy.

Treatment	Follow-up (months)	Natural erections (partial)	Vaginal potency With or without PDE-5 inhibitors
Oral drugs (USA)[62]	11	n/a	27%
VCD (Cleveland Clinic Foundation)[59]	9	37%	17%
MUSE (Cleveland Clinic Foundation)[60]	9	35%	39%
Injections (Cleveland Clinic Foundation)[66]	8	71%	28%
Injections (Italy)[58]	6	n/a	69%
Control (Cleveland Clinic Foundation)[60]	9	39%	11%

Abbreviation: n/a, not available.

19.6. Evolving Role of Robotic-Assisted Laparoscopic Prostatectomy

Ultimately, in several more years, we will have the answers as to which radical prostatectomy approach is best. Even though few small series have reported potency rates following radical perineal prostatectomy comparable to retropubic prostatectomy, the lack of concrete data on potency rates following bilateral nerve-sparing perineal prostatectomy puts this approach at the rear in this contemporary era.[15,17,18] It is well known that the laparoscopic approach reduces the number of hospital days and postoperative pain, but its role in returning sexual activity following surgery in younger patients is still unclear.[67] Reported potency rates following bilateral nerve-sparing LRP range from 14% to 81% and the majority of reports are European without validated questionnaires (Table 19.4).[25–31] It is still not definitive that the laparoscopic approach offers any advantage over conventional retropubic technique in terms of potency. The largest problem with the laparoscopic approach is that so few surgeons have the skill set to do bilateral nerve-sparing procedures well.

The potential of RALP in recovering early sexual activity however, looks promising at this time.[35,37,39–41] Table 19.5 shows that in 2006, RALP seems to be wining the race in terms of reported vaginal potency rates. Menon and colleagues reported potency rates following bilateral nerve-sparing RALP as 74% at 12 months. With preservation of prostatic fascia or the veil of Aphrodite, erections strong enough for intercourse were reported in 97% of patients 12 months following surgery.[39] It appears that experienced robotic surgeon needs only 400 to 500 cases to achieve potency rates that are substantially higher than previously reported in other literature. If these results can be replicated, RALP will become a new standard and state of the art in the treatment of localized prostate cancer treatment.

19.7. Is There Any Role of Early Penile Rehabilitation Following Robotic-Assisted Laparoscopic Prostatectomy?

While potency results following RALP are impressive at remarkably shorter intervals than previously reported in the retropubic literature, the ultimate quality of the erection as defined by IIEF-5 (SHIM) scores still remains less than baseline in most series. In 2005, Menon and colleagues reported with the standard VIP technique postoperative SHIM scores of 14.8 versus a baseline or preoperative score of 24.0.[39] Only with the prostatic fascia–sparing technique (the veil) did postoperative SHIM scores approach baseline values. With the veil technique, reporting at 12 months, Menon and coworkers reported a postoperative SHIM of 21.9, which was comparable to the preoperative SHIM of 24.5. Similarly, Joseph and associates assessed sexual function in 153 patients by IIEF-5 score following RALP in 2006.[43] Seventy of 153 pateints (46%) had a IIEF-5 score greater than 22 at six months following definitive surgery, leaving 54% with a result less than baseline function. All the patients in their series used oral PDE-5 inhibitors at least one month postoperatively. These two landmark studies substantiate postoperative potency rates defined by IIEF-5 scores rarely equal preoperative scores, and suggest a role or opportunity for early penile intervention.

Thus far, despite technically excellent nerve-sparing surgery done by robotic surgeons, we continue to observe a temporary period of neuropraxia.[35,36] While the robotic surgical system with its 3D vision and 10- to 15-fold magnification provides a significant technical advantage over conventional open surgery, reports still show erections sufficient for vaginal intercourse do not return for 3 to 12 months following surgery.[39,40,42–44] In 2003, Menon and associates reported in their interim results at six months the rate of partial erections and vaginal potency following RALP was 82% and 64%, respectively, in patients less than 60 years of age. Also in the same year, this group reported that only 50% of patients achieved return of partial erections at a mean follow up of 180 days (six months) and a return to vaginal intercourse at a mean of 340 days (11.3 months).[37] Similarly, Chien and associates reported return to baseline sexual function in 66% and 69% of patients less than 60 years old at 6 and 12 months following RALP, respectively. Although Ahlering and associates reported a vaginal potency rate of 43% at three months following their cautery free technique, their sample size was small and 67% of patients were still sexually inactive.[41] These reports illustrate that even with robotic technology performing nerve-sparing surgery, there occurs a significant period of neuropraxia. The ultimate outcome measure regarding potency and the approach will be the long-term follow-up. Thus far, the longest reported follow-up on a robotic series is 12 months, and it is becoming apparent that this endpoint may be premature. A recent study from our group would indicate that the attrition in potency or sexual activity (50%) in the first five years is significant.[71] The exact reasons for the attrition appear to be lack of interest and co-morbidities, but only 11% of these patients are naturally potent. This raises the ultimate question whether our early intervention strategies should extend into chronic intervention treatments. Would chronic therapy or chronic dosing ultimately mitigate this decline or attrition in sexual activity seen in our surgical prostate patient following definitive treatment? Whether patients are treated with prostate brachytherapy, external bean therapy, or radical prostatectomy, the vast majority of potent patients fail to ever recover their baseline status. This reality should help stimulate and drive the concept of chronic dosing for high-risk groups for erectile dysfunction. High-risk groups include patients with significant hypertension, hyperlipidemia, diabetes mellitus, and patients who receive definitive local treatment for localized prostate cancer.

19.8. Concept of Chronic Therapy

Erectile dysfunction is reported in 70% to 80% of patients five years following radical prostatectomy.[68,69] Penson and colleagues assessed temporal changes in sexual function in a cohort of 1288 men who underwent radical prostatectomy. They reported that at 60 months, 46% of patients reported no sexual activity, 77% of patients have little or no interest in sexual activity, and only 28% of the men had erections firm enough for vaginal intercourse.[70] It is unclear if the lack of spontaneous vaginal potency with or without oral therapy adversely affects the interest level.

Unfortunately, a significant attrition in potency is observed after five years in patients who have recovered natural potency following radical prostatectomy. At the 2005 American Urological Association meeting, Zippe and colleagues presented an abstract on the natural history of sexual activity of patients who have recovered potency following RRP (Table 19.15).[71] In this study, it was noted that after five years, only 11% of patients who were potent preoperatively were still having intercourse without erectaids. In this prospective study, 141 sexually active patients (mean age, 65.08 ± 6.68 years) who have undergone bilateral nerve-sparing radical prostatectomy between 1997 and 1999 were included. At one year, 113/141 (80%) patients were sexually active. Specifically, 3% were active naturally, 49% with PDE-5 inhibitors, 8% with MUSE, 23% with IC penile injections, and 17% with a VCD. The five-year analysis (mean follow-up of 6.4 years) showed that only 70/141 (50%) patients were sexually active. The two main reasons for sexual discontinuation included loss of interest and medical co-morbidities (cardiovascular and neurologic). If more sophisticated clinical inquires are done, the loss of interest and medical co-morbidities are probably interrelated to the loss of obtaining a natural erection easily with or without oral therapy. What becomes evident is that these patients are not being followed closely enough and opportunities for intervention, whether it is pharmacologic or psychological, are not being pursued. The subject of long-term desire and interest resulting from the loss of natural vaginal potency has not been appropriately studied in the urologic literature and illustrates the long-term marriage that exists between the prostate cancer specialist and erectile function.

Table 19.15. Natural history of sexually active patients (SHIM > 21) following radical prostatectomy at one and five years (n = 141; mean age, 65.08 ± 6.68 years; mean follow-up, 6.4 ± 1.5 years).

Vaginal potency	At one year [*n* (%)]	At five years [*n* (%)]
Total sexually active	113 (80)	70 (50)
Natural potency (no erectaids)	4 (2.8)	16 (11.3)
PDE-5 inhibitors	55 (48.7)	28 (40)
PDE-5 inhibitors plus (VCD, ICI, MUSE)	0	5 (7), 5 (7), 1 (1.4)
MUSE	9 (8)	0
ICI	26 (23)	10 (14.3)
VCD	19 (16.8)	5 (7.1)
Reasons for discontinuation of sexual activity		
Total	28 (14)	71 (50.4)
Loss of interest	10 (46)	44 (31)
Medical comorbidities (CVS & CNS)	0	25 (18)
Urinary incontinence	15 (53)	0
Loss of partner	0	3 (2.1)
Other	0	2 (1.4)

Abbreviations: CNS, please define; CVS, please define; ICI, intracavernosal penile injections; MUSE, medicated urethral system for erection; PDE-5, 5-phosphodiesterase inhibitors; VCD, vacuum constriction device.

In 2005, Stephenson and colleagues reported their outcomes from two major population-based studies: SEER and Prostate Cancer Outcomes Study (PCOS).[72] In this review, 1977 men with localized prostate cancer who received either external beam radiation therapy or radical prostatectomy between 1994 to 1995 were surveyed 6, 12, 24, and 60 months after the initial prostate cancer diagnosis. It was observed that 50.5% of the men used multiple types of erectaids for their erectile dysfunction during the 60 months following the prostate cancer diagnosis. The vast majority of these patients (38%) were compliant with oral therapy, but only 5.7% and 2% continued to use VCD and IC penile injections, respectively. The most satisfied group was the penile prosthetic group, but only comprised 1.6% of the patients. Men who used no treatment (49.2%) reported low sexual success, 50% of what was

Table 19.16. Treatment of erectile dysfunction at 12 and 60 months following radical prostatectomy and radiation therapy: outcomes from the SEER and PCOS.

Variables	12 months (% of patients)	60 months (% of patients)
Number of patients	1753	1462
Any ED treatment	25.4 ± 1.19	50.8 ± 1.53
VCD	9.8 ± 0.82	5.7 ± 0.69
Penile injection	6.6 ± 0. 68	2.0 ± 0.43
Non–sildenafil citrate medication	1.6 ± 0.32	0.8 ± 0.25
Psychosexual counseling	2.0 ± 0.44	0.8 ± 0.25
Penile prosthesis	1.1 ± 0.30	1.6 ± 0.35
Sildenafil citrate only	—	16.7 ± 1.18
Sildenafil citrate + others	—	20.9 ± 1.21
Other multiple treatments	4.3 ± 0.55	2.3 ± 0.47
No ED treatment	74.6 ± 1.19	49.2 ± 1.53

Abbreviations: ED, erectile dysfunction; PCOS, Prostate Cancer Outcomes Study; SEER, The Surveillance, Epidemiology, and End Results cancer registry; VCD, vacuum construction device.

predicted (Table 19.16). It was felt that this large no-treatment group resulted not only from patient reluctance but failure of the physicians to offer therapy. This report also concluded the effectiveness of currently available erectile dysfunction treatments is at best modest. Similar to the findings of Schover and coworkers,[13] their results indicate substantial room for improvement in the use, effectiveness, and acceptability of therapy for ED following treatment of localized prostate cancer. The comprehensive clinical review again illustrates the long-term marriage that is needed between the prostate cancer specialist and sexual longevity.

Definitive treatment of localized prostate cancer — whether it is surgery or radiation — is a significant co-morbidity in the sexual longevity of our younger patients. It is not any different in having a diagnosis of diabetes mellitus, severe hypertension, or hyperlipidemia requiring daily medication. In exploring the feasibility of a chronic therapy or dosing model, we choose to investigate a pharmacologic stimulus in a subset of patients who underwent prostate brachytherapy. We hypothesized beginning a daily oral dose of a PDE-5 inhibitor (sildenafil citrate) at the time of radioactive seed placement may mitigate the subsequent radiation damage and fibrosis. Between December 2002 and January 2004, data on 44 sexually active patients (mean age, 68.6 years) was collected. Group 1 (24 patients) received daily maintenance dose of sildenafil citrate (50 mg/day for 12 months, then as needed). The PDE-5 inhibitor was started immediately following brachytherapy [mean, 3 days (1–5 days)]. Group 2 (20 patients) did not receive any early treatment. All patients were assessed after a minimum follow-up of 12 months using IIEF-5. In group 1, IIEF-5 scores were totally preserved at 12 months follow-up (prebrachy IIEF score, 24 ± 3.0 vs. postbrachy IIEF-5, 21 ± 3.6). In group 2, there was a significant decline in IIEF-5 scores (prebrachy IIEF-5, 22.4 ± 2.67 vs. postbrachy IIEF-5, 10.6 ± 6.86 (Table 19.17).[73] This pilot study is one of the first models in the radiation literature to demonstrate that early intervention and perhaps chronic therapy may impact subsequent potency rates.

Applying a chronic therapy model to prevent ED in the current medical environment is probably unrealistic if we are asking patients to use a daily medicine for years and insurance payers to reimburse this request. However, it may be

Table 19.17. Response to IIEF-5 questionnaire by patients on chronic sildenafil citrate dosing following prostate brachytherapy.

IIEF-5 (SHIM)	Early sildenafil citrate group (n = 24; mean ± SD)		Control group (*n* = 20; mean ± SD)	
Follow-up (months)	14.4 ± 3.9		17.1 ± 4.0	
Status	Prebrachytherapy	Postbrachytherapy	Prebrachytherapy	Postbrachytherapy
Confidence	4	4	4.3 ± 0.48	2.8 ± 1.03
Erection firmness	4.5 ± 1.0	3.75 ± 0.96	4.7 ± 0.67	1.7 ± 1.25
Maintenance ability	4.1 ± 1.01	3.65 ± 0.87	4.8 ± 0.63	1.75 ± 1.3
Maintenance frequency	4.5 ± 1.03	3.79 ± 1.9	4.27 ± 1.08	2.3 ± 1.57
Intercourse satisfaction	4.5 ± 1.04	4.0 ± 1.1	4.8 ± 0.63	2.1 ± 1.05
Total	24 ± 3.0	21 ± 3.6	22.4 ± 2.67	10.6 ± 6.85*

Abbreviation: SD, standard deviation.

*$p < 0.05$.

possible to convince patients to use a daily medicine for the period of neuropraxia (0–12 months) following definitive prostate cancer treatments, and then use oral therapy as adjuvant treatment on an as-needed basis to augment erectile performance. A model of chronic maintenance therapy for ED in high-risk subsets needs to be explored further to help preserve sexual activity in our younger patients.

19.9. Conclusion

Dynamic themes, which emerged in 1990s regarding prostate cancer diagnosis and management, were largely due to mainstream use of PSA testing and office-based ultrasound-guided biopsy techniques. PSA screening contributed to detection of lower volume cancers, which increased biochemical cure rates upwards to 80% to 90%. A second important consequent of rigorous prostate cancer screening was that the patient age of diagnosis dropped substantially. The SEER cancer registry from 1995 to 1999 reported that 33% of all incident prostate cancer cases are diagnosed in men under age 65 years and this figure will invariably be higher in the subsequent five-year report. Younger cancer patients have higher expectations on quality of life issues — foremost, urinary incontinence and erectile function. It is the demand of the younger patients, which pushed many of us to consider early penile rehabilitation strategies to improve potency rates following radical prostatectomy.

When analyzing the reported potency rates following various radical prostatectomy approaches, we find the results from various procedures vary widely. Vaginal potency rate following RRP in the hands of experienced surgeons at centers of excellence ranges from 40% to 86%. Perineal radical prostatectomy, which did not gain universal popularity, suffered due the paucity of literature on potency rates in younger patients following bilateral nerve-sparing surgery. Reported potency rates following bilateral nerve-sparing LRP range from 14% to 81%. But very few surgeons can climb the steep learning curve necessary to perform bilateral nerve-sparing laparoscopic surgery well. While the short-term vaginal potency rates following robotic-assisted prostatectomy are unprecedented (43%–97%), erections sufficient for vaginal intercourse still require 3 to 12 months of recovery. This suggests that despite robotic technology and technically superior vision and magnification, we still have some degree of injury to the neurovascular bundle.

Our available clinical data on the early use of PDE-5 inhibitors, VCD, IC penile injections, and combinations of the above would suggest that there is a short-term benefit of 20% to 40% in the rate of vaginal potency and a 30% to 70% improvement in the rate of partial (spontaneous) erections. Thus, we conclude that an early program with one of the erectaids with or without a PDE-5 inhibitor improves erectile physiology and performance following radical prostatectomy. Logistically, the combination of a PDE-5 inhibitor and a VCD may prove to be the most user friendly, cost effective, and patient compliant. Ultimately, even with the superior potency results reported from robotic-assisted laparoscopic surgery, there will always remain a role for early intervention or penile rehabilitation therapies.

The sexual longevity of the prostate cancer patient, however, greatly exceeds the interval of current reporting. A number of recent studies illustrate the fact that nearly 50% of our baseline sexually active patients are no longer active at five years of follow-up. Several dominant issues have been identified in these databases. Patients exponentially lose their natural erectile ability to achieve vaginal penetration, requiring the frequent use of erectaids. The most compliant erectaids for the long-term are PDE-5 inhibitors, which usually require some degree of partial erections for success. The other issues that occur with longer follow-up include a loss of interest and fear or reluctance of sexual activity due to other co-morbidities. These issues illustrate the need and urgency of long-term care and follow-up by the prostate cancer specialist. Our future prostate cancer patient will be best served by a prostate cancer specialist who understands this long-term commitment.

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20

Robotic Pyeloplasty

Michael Louie, Robert I. Carey, Raymond J. Leveillee, and Vipul R. Patel

Over the last two decades, we have seen a significant paradigm shift for the treatment of ureteropelvic junction (UPJ) obstruction. While initially the only treatment option was an open surgical approach, the decades have shown an evolution towards less invasive therapies. The move towards minimally invasive surgery was attributed to the significant morbidity associated with an open flank incision. This has led to the growth of laparoscopic and endoluminal surgical options that provide the potential for decreased morbidity: less blood loss, less pain, shorter hospitalizations, and faster recovery.

Over the last decade, endourologic and laparoscopic techniques have become commonplace as firstline therapies for primary UPJ obstruction. Both have delivered the benefits of minimal access surgery with varying results. Laparoscopic pyeloplasty has evolved sufficiently now to be considered as a gold standard for treatment of UPJ obstruction with success rates greater than 90%.[1–3] Endourologic procedures, such as endopyelotomy, have a reported success rate of 50% to 88%.[4–10]

While minimally invasive therapies have now become quite popular, their use has been limited by various factors. Endopyelotomy has a significantly reduced success rate and the potential for significant bleeding; whereas the laparoscopic approach to pyeloplasty is quite technically challenging and therefore limited to those with laparoscopic expertise. The use of a robotic system to assist with laparoscopic pyeloplasty has refined the minimally invasive approach with delicate tissue handling and precise visualization of suturing. Robotic-assisted laparoscopic pyeloplasty contains the benefits of laparoscopic pyeloplasty and potentially improves upon the surgical experience with increased 10x magnification, three-dimensional (3D) vision, cancellation of tremor, motion scaling, and wristed instrumentation.

20.1. Ureteropelvic Junction Obstruction

Ureterpelvic junction obstruction is characterized by functional impairment in the urine flow from the renal pelvis to the proximal ureter. Most cases of UPJ obstruction present in childhood, and have been estimated to represent up to 48% of all neonatal hydronephrosis. By far it is the most frequent cause of neonatal hydronephrosis.[11] In adults, the most common cause of UPJ obstruction is a crossing vessel, with an estimated incidence of 29% to 65%.[12] The obstruction caused by these congenital crossing vessels usually do not manifest with symptomatic hydronephrosis until years later, when the patient is an adult. Besides congenital UPJ obstruction, adults may have acquired obstruction stemming from a history of stone disease, prior retroperitoneal surgery, urothelial cancer, or the obstruction may be inflammatory in nature.

20.2. Pathophysiology

The most common cause of congenital UPJ obstruction in the pediatric population is an adynamic ureteral segment.[13] These segments may be normal on gross inspection, and less frequently, a true ureteral stricture is found due to abnormal ureteral musculature. Ureteral mucosal folds that are typical of fetal ureteral development may also cause a kink or valve mechanism. Gross inspection of the UPJ often exhibits external fibrous bands or tethering of the UPJ. Indeed, freeing these bands may result in resolution of the obstruction, but often these bands are secondary to an inflammatory reaction from the chronic obstruction itself. Another consequence of these fibrous bands occurs upon filling of the renal pelvis with urine. As the pelvis fills, it moves anteriorly and inferiorly in relation to the proximal ureter beneath the fibrous tissue. This causes a functional obstruction by the severe angle at which the ureter inserts into the renal pelvis. The dependent portion of the renal pelvis becomes unable to drain appropriately, thus creating a continual cycle of obstruction, subsequent inflammation, and fibrous tissue formation. Similar to the problem of the fibrous band is the high insertion ureter. The ureter enters the renal pelvis such that the renal pelvis does not empty in a dependent fashion. High inserting ureters are usually found with renal ectopia or fusion anomalies.[12]

Despite the evidence supporting the role of crossing vessels in the formation of UPJ obstructions, there still remains controversy regarding exactly what that role entails.[11] These vessels appear to be normal variants of renal artery architecture; however, vessels that travel posterior to the ureter are strictly aberrant. Sampaio and Favorito[14] found that 65% of these vessels crossed anteriorly and that only 6.2% crossed posteriorly. These vessels originate at the aorta or split off the main renal artery to supply the lower pole of the kidney. The artery traversing the ureter in this fashion may cause a nutcracker phenomenon, by which the ureteral segment crossed by the vessel develops ischemia, and ensuing inflammation results in a chronic UPJ obstruction. However, there is also support for an intrinsic ureteral defect at the level of the crossing vessel, and that the vessel merely exacerbates the obstruction.[11]

Acquired lesions also cause UPJ obstructions in children, but are a more important etiologic factor in adults. In children, vesicoureteral reflux has been shown to cause ureteral tortuosity, and, along with infections, may cause inflammatory UPJ obstructions. In adults, acquired UPJ obstructions may be caused by fibroepithelial polyps, urothelial malignancies, postinfectious scarring, postoperative stricture, or ischemia. Treatment of these obstructive processes should always be aimed at the underlying condition.

20.3. Presenting Symptoms

The classic presenting symptom of UPJ obstruction is flank pain in the adult. The pain is commonly intermittent, waxing with the increased pressure on the renal pelvis as it swells with urine, and waning with the slow drainage of the renal pelvis and decreasing pressure. Generalized abdominal pain may also be a presenting symptom. Dietl's sign is described as abdominal pain with the ingestion or administration of diuretics. Similar to a provocative test, a patient may complain of renal colic after ingesting an alcoholic or caffeinated beverage as the renal pelvis swells from the diuresis. Gross painless hematuria may also be present, either spontaneously or with minor trauma. In the pediatric population, UPJ obstruction may be manifested by flank mass on physical examination. The increasing use of prenatal ultrasound has allowed the earlier diagnosis of UPJ obstruction in children.

20.4. Diagnosis

The diagnosis of a UPJ obstruction requires a functional study to determine the presence of an obstruction in addition to any clinical symptoms. Various imaging modalities have been used to both identify UPJ obstruction and determine its significance. Anatomical studies include intravenous pyelogram (IVP), renal ultrasound (RUS), and computerized tomography (CT) of the abdomen and pelvis. Magnetic resonance imgaing (MRI) urography has been reported, but does not represent a widely available nor cost-effective study. The diuretic renal scan is the standard modality to determine the significance of obstruction and to determine the relative function of the obstructed kidney. The Whitaker test had been the gold standard in determining UPJ obstruction, but has been supplanted by diuretic renography as the gold standard due to its invasiveness and its low sensitivity.[13] The Whitaker test is currently used only if other tests are indeterminate or conflicting.

Intravenous pyelogram is the standard test to delineate both anatomy and function in UPJ obstruction. This is an appropriate test for patients with normal renal function, with no intravenous (IV) contrast allergy, and who are not pregnant.[13] Obstruction is visualized as delayed filling of a dilated proximal collecting system with a distinct transition point between the renal pelvis and the proximal ureter. Oftentimes, a crossing vessel may be implied by a kink at the transition point or an unexpected curve in the proximal ureter. However, if the UPJ obstruction is severe, then no contrast will be seen on the affected side during the duration of the imaging.

Renal ultrasound is a good anatomical study, but is unable to reveal any functional information. It is commonly used first in the pediatric population, in pregnant patients, in azotemic patients, and in patients with contrast-induced allergies. Besides evaluation of the renal parenchyma, ultrasound is capable of determining the presence of hydronephrosis. Hydronephrosis appears on ultrasound as an anechoic mass separating the central echo complex of the renal hilum. Ultrasound is inaccurate, however, in determining whether or not obstruction exists.

Unenhanced helical CT scan is widely accepted method of diagnosis. It provides excellent anatomic detail and easily reveals hydronephrosis, but does not show functional significance of the hydronephrosis unless contrast-enhanced images are taken and compared with delayed images. Unenhanced helical CT is the gold standard for the detection of renal calculi, and oftentimes is the study initially performed for flank pain. UPJ obstruction can be diagnosed with a hydronephrosis leading to a normal proximal ureter. Besides identification of a transition point, CT scan may reveal perinephric stranding, periureteral edema, renal swelling, and a crossing vessel.

Diuretic renal scan is a noninvasive measure of renal function and allows washout of the collecting system to determine functional significance of an obstruction.[15] There is less radiation exposure than for an IVP and no risk of contrast allergy. The most widely used radionuclide used is technetium Tc 99m mercaptoacetylriglycine (^{99m}Tc-MAG3). The radionuclide is excreted through the renal tubules at the loop of Henle. In order to perform the procedure, patients are well hydrated. Patients must be able to void completely. Those unable to void completely must have a catheter placed. Normal renal function is important in determining the response of the kidneys to the diuretic. A sufficient flow rate must be induced by the diuretic in order to detect obstruction. In cases of decreased creatinine clearance, increased diuretic amounts may be used to decrease the possibility of a false-negative result. The timing of the administration of the diuretic is key. The diuretic is given 20 min after the radionuclide is administered. This has been called the F + 20 technique. If there is prompt washout, then no obstruction exists. If the $t_{1/2}$ of the clearance of the radionuclide in the collecting system is greater or equal to 20 min, then the collecting system is obstructed. Partial obstruction may exist or renal impairment may cause indeterminate clearance curves. If this is the case, the diuretic may be given 15 min prior to radionuclide administration, to achieve a normal washout curve. This is called the F-15 technique.

The Whitaker test was the standard for diagnosing obstruction in the collecting system, but has been largely abandoned in favor of the diuretic renal scan. The test directly measures the pressure difference between the renal pelvis on the affected side and the bladder. The patient is placed on a fluoroscopy table, and a bladder catheter is used. A nephrostomy tube with a pressure transducer tip is inserted into the affected kidney. A mixture of saline and contrast is infused into the renal pelvis at 10 mL/min. If the pressure in the renal pelvis increases above 22 cm H_2O then there is obstruction. If the pressure is less than 15 cm H_2O, then there is no obstruction. Any pressures in between 15 and 22 cm H_2O were indeterminate. Fluoroscopy is used to identify the anatomic transition point if there is obstruction. The requirement of radiation exposure, bladder catheterization, and a renal catheter make the Whitaker test quite invasive, and therefore rarely performed.

20.5. Indications for Treatment

The currently accepted indications for the treatment of UPJ obstruction include symptomatic obstruction, formation of stones or infection, decrease in overall renal function or worsening ipsilateral renal function, and rarely, hypertension.[13] The goal of treatment is a restoration of urine flow and improvement or return of renal function. If the patient presents with physiologically indeterminate obstruction, then the option of observation with serial imaging studies may be appropriate. The patient whose overall renal function is decreased in a solitary kidney or bilaterally involved disease mandates a pyeloplasty be performed. In children with UPJ obstruction, similar criteria are used to determine when a pyeloplasty is indicated. However, controversy still remains as to the optimal timing of repair in the neonate.[11]

20.6. Therapeutic Options

Kuster described the first successful pyeloplasty in 1891. Since that time there has been a tremendous evolution in the technical approach. The Anderson–Hynes pyeloplasty has since become a gold standard by which we measure other surgical therapies with success rates in the literature between 95% to 99%.[16,17] However, with advances in endoscopic and laparoscopic techniques and equipment, many have sought to challenge the open pyeloplasty standard. Endoscopic therapies include balloon cautery endopyelotomy and direct vision endopyelotomy. Laparoscopic pyeloplasty procedures emulate the array of open pyeloplasty techniques. The most successful of the laparoscopic pyeloplasty techniques has been the dismembered pyeloplasty. The approach in laparoscopy may be retroperitoneal or more commonly, transperitoneal. The success rates for laparoscopic pyeloplasty are approaching open pyeloplasty rates as more surgeons become facile with laparoscopy and more pyeloplasties are performed in this manner.

Laparoscopic pyeloplasty has a steep learning curve despite the improving success rates and increasing laparoscopic procedures being performed. The technical challenges include difficult two-dimensional (2D) vision and intracorporeal laparoscopic suturing. Robotic-assisted laparoscopic pyeloplasty addresses these challenges with ease by allowing 3D vision with magnification, movement of the laparoscope onto the renal hilum for improved delicate dissection, tremor attenuation by the robotic arms that also improves the delicate dissection, and the six degrees of freedom by the wristed instrumentation that allows gentle manipulation of the tissues for suturing.

20.7. Robotic-Assisted Pyeloplasty

As laparoscopic pyeloplasty has become a gold standard for treatment of UPJ obstruction, an increasing number of urologists have attempted to learn this operation. The learning curve for novice laparoscopists is often quite steep due to the limitations of conventional laparoscopic surgery. The robot was initially looked upon as a tool to transition from surgeons from open to laparoscopic surgery. However, studies soon showed that the robot was not just a transition tool, but in many ways showed improvement and a broader application compared to standard laparoscopy.

The first robotic-assisted pyeloplasty was described by Sung and colleagues.[18] Their porcine model compared only the pyeloureteric anastomosis time and tightness of the anastomosis between traditional intracorporeal laparoscopic suturing and robotic-assisted suturing. The robot had increased anastomosis times, but the tightness of the anastomosis was equal between the two groups of pigs on visual inspection with indigo carmine and ex vivo retrograde ureteropyelogram. The robot in this case was the Zeus® robot (Computer Motion, Santa Barbara, CA) with an Automated Endoscopic System for Optimal Positioning (AESOP) attachment. Soon afterward, this same group compared the Zeus® to the da Vinci® robotic system (Intuitive Surgical Inc., Sunnyvale, CA) in performing various laparoscopic procedures on the porcine model.[19] They were able to perform the anastomosis faster and secure it with more bites by using the da Vinci® system. The comparison between the two systems revealed that the da Vinci® robot was more technically intuitive to use, thereby decreasing the learning curve.

20.8. Patient Positioning

The operative table and the da Vinci® platform are positioned at a either perpendicular or at a 45° angle relative to one another in the room depending upon trocar placement so that the robot will be pushed in a straight line to the patient for the eventual docking, thus minimizing table rotation at the time of docking. This is illustrated in Figure 20.1.

Patients are positioned in a modified flank position with a 30° incline. An orogastric tube and urethral Foley catheter are placed prior to positioning. The ipsilateral arm is positioned in an AMSCO Krause arm support BF10000 (Steris Corp., Mentor, OH) that is placed above the chest to allow the robotic arms space to maneuver. The contralateral arm is placed on a standard arm board flexed at 45°. A subaxillary roll is placed at nipple level, the bottom leg bent at 45° and the top leg bent at 10°. All pressure points are padded and the patient held in place with a desufflatable bean bag (Olympic Vac Pac, Olympic Medical, Seattle, WA) and heavy tape. The patient is prepped widely from the xiphoid process to the symphysis pubis. Note that major differences exist between the standard laparoscopic positioning and that of the robotic-assisted system. The ipsilateral arm must lie low and cephalad enough to allow for the midline robotic trocar and working element to be positioned without interference. If the contralateral arm is placed at a 75° to 90° angle, it will be in the way of proper docking of the robot. The contralateral arm to the kidney being treated is therefore secured at a 45° angle on a flat arm rest. Both arms are carefully padded with foam and secured with ACE bandages. The patient is further secured at the arms, chest, hips, and legs with cross-table 3-inch cloth tape. The bed is tilted fully right and left prior to draping to ensure that there is no patient slippage.

20.9. Trocar Placement

The standard trocar placement is shown in Figure 20.2, which illustrates the arrangement for a right-sided pyeloplasty. A mirror image arrangement is used for the left side. Pneumoperitoneum is established using a Veress needle or open exposure at the umbilicus or in the ipsilateral upper quadrant. For the vast majority of patients, the 12-mm camera port is placed at the inferior crease of the umbilicus. One of the 8-mm working arm ports is placed 8 to 10 cm superior to the camera port in the midline and the second is placed 8 to 10 cm lateral with a 10° inferior angle from the umbilicus. The infraumbilical camera port placement gives excellent vision of the UPJ and is preferred for cosmesis. The placement of the lateral trocar site is made only after inspec-

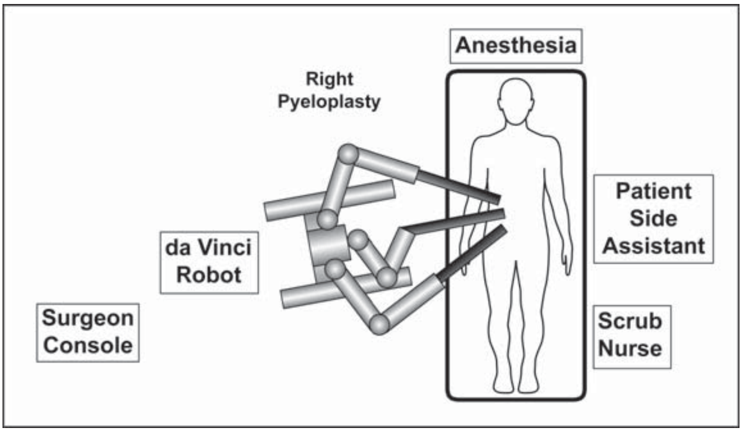

FIGURE 20.1. Schematic of room configuration for a three-port robotic-assisted laparoscopic right pyeloplasty. The patient is in the modified flank position at 60°.

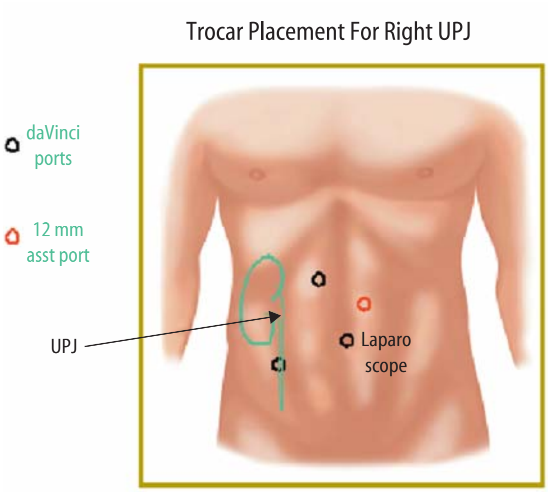

FIGURE 20.2. Incision from open pyeloplasty (left) compared to trocar-site incisions from robotic-assisted laparoscopic pyeloplasty (right).

tion of the abdomen. Minor adjustments may be made if the patient has unusual body habitus or has had previous surgeries. The initial Veress needle placement is done in the ipsilateral upper quadrant for patients who have had previous surgical incisions at the umbilicus. For patients who are morbidly obese, trocar placements are kept in the same arrangement, but a preoperative decision is made to shift the midline ports to a paramedian point.

20.10. Surgical Technique

The approach to robotic pyeloplasty can be either completely robotic or a hybrid procedure between standard laparoscopy and robotics. The later method has been preferred by most as the dissection is performed laparoscopically and the anastomosis robotically. This is due to the ease of manipulating the bowel and the kidney with standard laparoscopic instruments. During the pyeloplasty all fundamental steps of a traditional Anderson–Hynes dismembered pyeloplasty, an YV pyeloplasty, or a nondismembered Fenger pyeloplasty are performed precisely, without compromise compared to the open surgery. Using pure laparoscopic technique, the bowel is mobilized and retracted medially. The da Vinci® system may be docked at any point in the dissection after the bowel has been mobilized. Pararenal dissection is performed to expose the gonadal vessels and ureter, which are then dissected to the level of the renal hilum and renal pelvis. The presence or absence of crossing vessels is established and the full anatomy of the ureteropelvic junction is exposed. Crossing vessels are spared. The renal pelvis and ureter are mobilized and an intraoperative decision is made regarding the type of repair to be done. Extensive dissection of the ureter is avoided to prevent devascularization of a ureteral segment. The ureter is cut, spatulated, and transposed over the crossing vessels. Flexible nephroscopy and stone extraction may be performed at this time if necessary. The anastomosis is started at the apex and can be performed with either interrupted sutures, a single-knot running technique, or with two hemicircumferential running sutures that are run anteriorly and posteriorly and tied at the superior portion of the anastomosis. The University of Miami surgeons have preferred using interrupted sutures using a 3–0 vicryl on an RB-1 needle. The Ohio State University prefers the use of two five-inch running 4–0 monocryl sutures on a RB-1 needle due to the increased efficiency and watertight anastomosis provided by the running stitch.

20.11. Clinical Outcomes

The initial human series described the classical Anderson–Hynes dismembered pyeloplasty in nine patients using the da Vinci® robot.[20] Five of these initial patients underwent retrograde stent placement just before the operation. The remaining four patients had antegrade stents placed laparoscopically. They used three ports for the robot and one port for the assistant. Mean operative time was 138.8 min, mean suture time was 62.4 min, average blood loss was less than 50 mL in all cases, and mean hospital stay was 4.7 days. One patient required open exploration and repair for a persistent renal pelvis defect after pyeloplasty. Follow up at three months was complete in five patients. All five patients had subjective and imaging proven improvement. The authors included neither radiological criteria for UPJ obstruction nor criteria for obstruction improvement. They proved, however, that robot pyeloplasty had the ability to emulate the open procedure similar to laparoscopic pyeloplasty.

Gettman and colleagues later compared robot pyeloplasty with standard laparoscopic pyeloplasty.[21] Six patients in the robot group were compared with similar laparoscopic patients. Four patients underwent dismembered pyeloplasty and two underwent Fenger pyeloplasties. All patients were stented immediately prior to the operation. Mean operative time and suturing time was less for the robot pyeloplasties, but blood loss, hospital stay, and complications were similar. Suturing and operative time differences may have been even greater between robotic and standard laparoscopic pyeloplasty because all standard laparoscopic procedures underwent extracorporeal tying versus robotic intracorporeal tying. Short-term results at three months showed 100% subjective and imaging proven success. They updated this series two years later with a total of 49 patients.[22] Ten of these patients had initially failed endopyelotomy. Mean operative time was 124 min. Estimated blood loss was less than 50 mL. Follow-up for 41 of the 49 patients at a mean of 7.4 months revealed 100% success with diuretic renal scan or IVP.

Following these early successes, several other groups began reporting their experiences with robotic-assisted laparoscopic pyeloplasty. Most of these groups performed a hybrid approach with the initial dissection of the bowel, renal pelvis, and proximal ureter being performed using standard laparoscopic techniques, and then using the robot to perform the ureteropelvic anastomosis. Their short-term outcomes were similar with at least 94% success rates, and minimal complications. The University of Miami reported 26 patients that underwent robot assisted pyeloplasty.[23] Of these patients, four had secondary UPJ obstruction. All patients had preoperative retrograde ureteral stents placed. There were only three minor complications including postoperative fever, a urine leak managed conservatively, and an umbilical hernia. Follow-up with diuretic renal scan was performed at one month after stent removal and then six months later. At six months follow-up, subjective improvement was 95%, while there was 100% success with diuretic renal scan.

At the same time, three medical centers in New York City released a collective study on their own robot pyeloplasty experience.[24] The New York collective reported on 35 patients over three years, of whom two had a secondary UPJ obstruction. This group did not preoperatively stent their patients based on their experience with excessive peri-ureteral edema and inflammation in the UPJ. This inflammation may increase the risk of anastomotic leaks and may cause the tissue to be more friable. Mean follow-up was 7.9 months and consisted of a diuretic renal scan at three months, then yearly. They reported an overall success rate of 94%.

Bentas and colleagues reported the first 12-month study on pyeloplasties performed entirely with the da Vinci® robot.[25] Their series had 11 patients that underwent IVP or ultrasound at 3 and 12 months with a diuretic renal scan performed at 3 months. Diuretic renal scan showed no obstruction in any of the patients for an objective success rate of 100%. All patients had primary UPJ repairs.

Another completely robotic-assisted series from New Orleans showed similar success in 32 patients.[26,27] They included five pediatric cases: two patients were 6 and 8 years old, while three were 13 to 15 years old. Instead of a ureteral stent, all patients had a ureteral catheter placed just distal to the UPJ with the rest of the catheter prepped into the operative field. This catheter was then used as a guide to insert a stent in retrograde fashion intraoperatively. All cases were performed transperitoneally, including the pediatric cases. At six months follow-up, 16 of 18 patients exhibited improved drainage and were asymptomatic.

The largest series of completely robotic-assisted laparoscopic pyeloplasties with at least 11 months of follow-up was reported by Patel.[28] Fifty patients all underwent Anderson–Hynes dismembered pyeloplasty. Most patients were discharged on postoperative day 1. Ureteral stents were removed at three weeks. Patency of the UPJ was followed by diuretic renal scan at one month, then every three months in the first year, then every six months for the second year, and then yearly. There were no complications, and blood loss was minimal in all cases. Forty-eight of 50 (96%) patients had both objective and subjective improvement.

20.12. Cost

Recently, cost analysis was performed comparing da Vinci® robot–assisted pyeloplasty with laparoscopic pyeloplasty.[29] The assumptions made were equivalent hospitalization, operating room (OR) costs, success rates, complications, and professional fees. Five-year depreciation for the daVinci® robot was made based on 150 cases per year, and for laparoscopy an extra video tower was depreciated based on 400 cases per year. Disposables such as the daVinci® instrument lifetime of 10 cases and the Endostitch (Ethicon EndoSurgery, Cincinnati, OH) device were also factored. Holding the robot pyeloplasty OR time constant at a value of $5616, laparoscopic pyeloplasty was more cost effective if OR time was less than 338 min. Conversely, when laparoscopic pyeloplasty cost was held constant, robotic pyeloplasty did not reach an equivalent cost even at more than 500 cases per year. Two-way analysis between OR time and robot cases per year was performed showing that even at 500 cases per year, operating time would need to be less than 130 min per case in order to achieve an equivalent cost with laparoscopic pyeloplasty. However, despite the potential for increased cost, the decreased learning curve, ability of the robot to allow a broader application to more urologists, and the excellent early outcomes pyeloplasty has spurred growth in the procedure.

20.13. Conclusion

Robotic-assisted laparoscopic pyeloplasty has become the standard of care for treatment of ureteropelvic junction obstruction in almost all centers where a da Vinci® platform is available. Although decision tree and direct comparison analyses of cost suggest that the most cost-efficient means of treating UPJ obstruction is not presently with robotic assistance, cost is only one of many factors to be considered. Short-term follow-up of robotic-assisted laparoscopic pyeloplasty suggest that the clinical and radiographic success rates approach that seen with open pyeloplasty and are superior to endoscopic techniques of incision or dilation. The improved vision and precision associated with robotic assistance compared to traditional laparoscopy makes it attractive to experienced laparoscopic surgeons and novices alike wherever the robotic technology is present.

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21

Robot-Assisted Radical Cystectomy and Urinary Diversion

Ashok K. Hemal and Mani Menon

The technique of robot-assisted radical cystectomy (RRC) allows precise and rapid removal of the bladder with minimal blood loss, which is translated in to minimal morbidity with equivalent success to open surgery to the patient. Herein, we briefly describe this new technique of robotic radical cystectomy and urinary diversion with review of the published literature. The potential advantages of robot-assisted surgery can be transferred in complex and advanced uro-oncologic surgery such as bladder surgery. However, long-term oncological and functional outcome are yet awaited.

21.1. Introduction

Bladder cancer, the fourth most common cancer in men and the eighth most common cancer in women in the United States,[1] is prevalent world wide. Superficial bladder cancer can be effectively treated with transurethral resection and with or without intravesical instillation of immunotherapeutic and chemotherapeutic agents, and there have been trials conducted for the advanced cancer of the bladder with neoadjuvant chemotherapy and radical cystectomy versus radical cystectomy alone.[2] However, the surgical removal of the bladder, such as radical cystectomy anterior exenteration, for muscle-invasive cancer has been considered as the most effective treatment.[3] This surgical procedure is associated with significant complications even in the hands of an experienced surgeon.[4]

Laparoscopic surgery has already established its horizon in the field of urology, and has been used for the variety of indications of surgery, ranging from benign to malignant urological diseases. Despite the feasibility and safe employment of laparoscopic radical cystectomy (LRC) for the management of muscle-invasive cancer of the bladder, it has not been established universally over the last 15 years. Not only that, but randomized controlled trials are lacking. Currently, LRC is being performed in limited centers worldwide by highly experienced laparoscopic surgeons.

At present, LRC remains difficult to learn and master. Removal of muscle-invasive cancer bladder has been employed laparoscopically with extracorporeal diversion[5–10] or completely intracorporeal urinary diversion, such as ileal conduit or different form of continent urinary diversion.[11–13] There are two large reported series of LRC comprising of 84 and 50 patients clearly demonstrates that the operative time and complication rates can be reduced significantly.[14,15] Although open radical cystectomy is safe in skilled and expert hands, it remains a formidable procedure with complications and entails long incision, exposing patient to incision-related morbidity and longer hospital stay.[16] Needless to say that laparoscopic radical cystectomy is also not free of complications and more so during initial experience.[17,18] Despite 15 years of development of laparoscopic urologic surgery, laparoscopic radical cystectomy, especially urinary diversion, has not gained widespread acceptance yet owing to its technical difficulty. Therefore, the technical advantages that robotic assistance offers, such as magnified three-dimensional vision, endowrist, and ability to perform fine complex surgical repair has been employed in such procedures.[19–21]

Menon and colleagues were first to develop the technique of robotic radical cystectomy and demonstrated amply its utility in first large case series published in early 2003.[19] The currently used surgical technique is described herein.

21.2. Surgical Technique

Robot-assisted radical cystoprostatectomy (RRC) and urinary diversion can be performed as one step or using a three-step approach.[21]

In the single-stage technique, RRC and intracorporeal urinary diversion, such as ileal conduit or different form of continent urinary diversion, can be performed entirely with robotic assistance.[22]

Bowel preparation was done in all patients. Third-generation cephalosporin and metronidazole was administered an hour before surgery and continued postoperatively. All pressure points were protected by appropriate padding. Patients were positioned in the extended tilt. Stockings were used to prevent thromboembolism.

A Foley catheter and nasogastric tube were inserted. A five- or six-port transperitoneal technique was used. Creation of pneumoperitoneum and nuances in port placement had been described in the literature.[23]

After initial port placement, then peritoneal cavity and intraabdominal organs were inspected using a 0° lens. If there were adhesions, then adhesiolysis was carried out. The list of instruments required are described in Table 21.1.

21.2.1. Step I

In the three-step technique, first, using the da Vinci® Surgical System (Intuitive Surgical Inc., Sunnyvale, CA), a complete extended pelvic lymphadenectomy and cystectomy or cystoprostatectomy is performed utilizing a posterior technique developed specifically for robotic cystectomy.[19,20]

21.2.1.1. Bilateral Extended Pelvic Lymphadenectomy

The bilateral extended pelvic lymphadenectomy is performed at the beginning or after radical cystectomy and the anatomic limit of extended lymphadenectomy duplicates with standard open surgery. The dissection is performed with robotic bipolar forceps in left hand and robotic articulating scissors in the right hand. The limit of dissection is Cloquet lymphnode distally, genitofemoral nerve laterally, and the bifurcation of the common iliac artery proximally. The loose fibro-areolar tissue is swept off the psoas muscle medially, then external iliac artery, external iliac vein, and obturator nerve are skeletonized, extending proximal limit dissection up to bifurcation of commom iliac artery. While dissecting distally, one has to be cautious of accessory obturator vessel and anomalous vein, often hidden behind the lymphnode. Similarly, while skeletionizing external iliac vein, extreme care is taken as the pneumoperitoneum appears flat. Lymphadenectomy requires a very cautious approach because the tissue contains multiple small blood vessels that have to be meticulously coagulated. Otherwise, they retract into the tissues and give rise to hemodynamically insignificant but visually annoying oozing. This impairs visibility and may obscure the detection of precise tissue planes. After completion of lymphadenectomy, lymphnodes are secured inside Endocatch™ I bag (US Surgical, Norwalk, CT).

Initially, we had started by performing a bilateral extended pelvic lymphadenectomy (PLND), ligating the superior and inferior vesicle pedicles as the operation proceeded. However, extended PLND prior to cystectomy was difficult, particularly in obese patients, in patients with a narrow pelvis, in those with bulky tumors, or in those with pelvic inflammation secondary to Bilharziasis. Therefore, in such cases lymphadenectomy is performed at the end of radical cystectomy.

21.2.1.2. Posterior Dissection

The posterior dissection is commenced with an inverted U-shaped incision in the peritoneum of the cul de sac. In many patients (especially thinly built patients), the course of the lower ureters can be seen through peritoneal fold that extends from the iliac bifurcation to the posterior bladder wall. When this is seen, the vertical limbs of the U follow this course, extending proximal to the

Table 21.1. Robotic and laparoscopic instruments used during different steps of robotic radical cystectomy.

Steps of robot-assisted radical cystectomy	Endowrist® instruments	Lens	Suture	Comments
Placement of ports		30° angled up		Patient position, steep Trendlenburg
Peritoneoscopy, adhesiolysis, release of sigmoid colon	Long-tip forceps, permanent cautery hook OR round tip scissors, Maryland bipolar forceps	30° angled up or 0°		Laparoscopic instruments are used for initial adhesiolysis for placement of the ports
Mobilization of the ureters		30° angled down or 0°		
Bilateral extended pelvic lymphadenectomy	Round tip scissors, PreCise bipolar or Maryland bipolar forceps	0°		Lymph nodes are placed in the Endocatch™ bag and retrieved during removal of specimen
Posterior dissection, vas deferens and seminal vesicle dissection, control of the bladder pedicles, control of prostatic pedicles, incision of Denonvilliers' fascia, and dissection posterior to the prostate	Round tip scissors, PreCise bipolar or Maryland bipolar forceps Hem-o-lok clips	30° angled down or 0°		Laparoscopic graspers and suction are very helpful during these steps
Dissection of the bladder off anterior abdominal wall with division of medial umbilical ligaments and urachus	Long tip forceps, permanent cautery hook	30° angled up		
Apical dissection, control of dorsal venous complex, and transection of the urethra	Two large needle drivers for suture and round tip scissors, PreCise bipolar or Maryland bipolar forceps for transection	0°	0 vicryl (polyglactin 910) on CT1 (36.4-mm) needle	
Preservation of the neurovascular bundles-	Round tip scissors, PreCise bipolar or Maryland bipolar forceps for transection	0°		
Extraction of the specimen	Endocatch™ II bag			
Urethra–neobladder anastomosis	Large needle driver or long-tip forceps, which helps in holding the bowel		3-0 monocryl (poliglecaprone 25) on RB1 needle	

Laparoscopic instruments used in the procedure are graspers, suction, scissors, and clip applicator.

bifurcation of the common iliac artery. All fatty and fibrovascular tissue is dissected off the posterior peritoneal fold. The posterior layer of Denonvilliers fascia is incised in the midline and the plane between the rectum and the bladder is developed as far inferiorly as is easily possible. The planes are extended laterally, such that a broad dissection front is maintained. This leads to the ureter, which lies on the under surface of the posterior peritoneum. The ureters are dissected to the bifurcation of the iliac vessels proximally and the ureterovesical junction distally. In males, the ureterovesical junction can be identified immediately inferior to the crossing vas deferens on the posterior bladder surface. It is important not to dissect the vas deferens off the posterior surface of bladder, to maintain this anatomical landmark. The inferior vesicle pedicle is usually encountered during this phase of the dissection and must be secured and divided. The ureter is then clipped, transected, and the margins sent for frozen section. The seminal vesicles are identified immediately medial to the lower end of the ureters. These are dissected down to their base. This plane of dissection also provides opportunity to begin preserving the neurovascular bundles, if indicated, even before the anterior and latter bladder dissection is performed. The rectoprostatic plane is now developed as feasible by dividing Denonvillier's fascia.

21.2.1.3. *Mobilization of the Bladder, Control of the Bladder Pedicles, Endopelvic Fascia Incision, and Control of Dorsal Vein Complex*

The bladder is dissected off the anterior abdominal wall by incising the anterior peritoneum. This incision is lateral to the medial umbilical ligament (obliterated umbilical arteries) on either side and transects the vas deferens, if not divided earlier. The incision then curves medially under the rectus abdominis, transecting the medial umbilical ligaments and the urachus. Thus, prevesical space is entered and it is dissected further down to expose the space of Retzius. The superior vesical pedicle is clipped and transected at its origin. The anterior trunk of the internal iliac artery continues as the inferior vesical artery is secured now if not done during the earlier posterior dissection. The endopelvic fascia is now opened lateral to the prostate and the prostate–urethral junction is identified. The dorsal vein complex is secured using a figure 8 suture of 0 vicryl on a CT1 needle, and prostatic dissection is done as previously described.[24]

21.2.1.4. *Preservation of the Neurovascular Bundles*

In young patients with localized disease, dissection is performed in the plane between the posterior surface of seminal vesicle and the posterior layer of Denonvillier's fascia. Monopolar coagulation is avoided, and the da Vinci® articulated scissors and bipolar forceps are used for this step. Dissection should be meticulous and stay close to the prostatic surface, reflecting the lateral pelvic fascia off the prostate. Such precision is possible with the good vision and depth perception and also because the vesical and prostaic pedicles have been controlled at this point. The prostate is benign, thus sparing the neurovascular bundles is easy and, if it is decided to preserve them, these are reflected off laterally, leaving a layer of Denonvillier's fascia on the surface of the rectum.

21.2.1.4. *Division of Urethra*

The urethra is divided at the apex of prostate. The division of the posterior striated sphincter should be done carefully with an attempt to gain good length of urethra, which would help subsequently in anastomosis with neobladder. In order to divide the anterior wall of the urethra, puboprostatic ligaments, the ligated deep dorsal vein complex, and the striated urethral sphincter are divided; then, the posterior wall of the urethra is divided and freed from the rectourethralis muscle and Denonvilliers' fascia. Infrequently, after division of the urethra, oozing may start from the dorsal venous complex, which can be fulgurated or a suture can be reapplied. The specimen is entrapped in Endocatch^{TM} II bag.

21.2.1.6. *Extraction of the Specimen*

A midline vertical incision is made in the hypogastrium near the umbilicus to retrieve the specimen. Because the urethra–neobladder anastomosis is performed with robotic assistance, work is allowed deep down in the pelvis and a long incision extending to hypogastrium is not needed, which is otherwise essential during this step in open surgery.

In female patient, the specimen can be removed from the vagina. Thus, there is no incision on the abdominal wall if urinary diversion is performed intracorporeally.

21.2.2. Step II: Urinary Diversion

An ileal conduit, a W-pouch with a serosal-lined tunnel or double chimney, or a T-pouch with a serosal-lined tunnel can be reconstructed through the site of incision from which specimen is removed.[21] Most frequently, orthotopic neobladder (detubalarized ileal W-bladder) is performed unless there is specific contraindication. After creation of pouch, the suture line of the most dependent portion of the pouch is opened for 2 cm to anastomose with the urethra. The pouch is now ready to transfer to the pelvic cavity. Ileal conduit and another form of diversion are well described and the same principles were followed.[21]

21.2.3. Step III: Urethra–Neobladder Anastomosis

The reconstructed neobladder pouch is placed in the pelvis and a Foley catheter is passed per urethrum into the pouch, through the neobladder neck. The pouch is pulled down to the urethra with the help of inflated balloon. The abdominal incision is closed and the robot is re-installed for anastomosis of neobladder with urethra. The urethra–neovesical anastomosis is performed robotically with a continuous double-armed 3-0 polydioxane suture or interrupted vicryl sutures. This anastomosis is performed based on our previously laid down principles for robotic radical prostatectomy.[24]

21.3. Postoperative Care

Patients are kept in recovery for few hours postoperatively then were shifted to their room. The nasogastric tube is removed the next morning and oral liquids started unless there are some contraindications. Mobilization, leg exercises, and chest physiotherapy started on first postoperative day. Drain was removed usually 48 to 72 hours postoperatively. Subsequent, follow-up is done based on type of urinary diversion.

21.4. Results

Robot-assisted radical cystoprostatectomy (RRCP) was carried out in 21 males and robotic-assisted radical cystectomy (RRC) in three females.[21] In males, the technique of nerve-sparing radical cystoprostatectomy with robotic assistance is used. In females, the operation was performed with the conventional anterior approach in one patient and with a new technique in two patients, which allows preservation of urethra, uterus, vagina, and both ovaries.[20]

The form of urinary reconstruction was ileal conduit (4 patients), W-pouch with a serosal-lined tunnel (16 patients) or double chimney (2 patients), or a T-pouch with a serosal-lined tunnel (2 patients). The mean operating times for robotic radical cystectomy ranged from 110 to 170 min and for urinary diversion from 120 to 180 min.[19–21] The mean blood loss was in the range of 100 to 300 mL. All the procedures were completed without any intraoperative complication or conversion to laparoscopic or open surgery. None of the patients were given a blood transfusion. The number of lymph nodes removed was in the range between 3 and 27, with one patient having N1 disease. The margins taken from the lower end of ureters were tumor free. The margins of resection were free of tumor in the specimens of all patients. On long-term follow-up, a case of port site metastases after robot-assisted laparoscopic radical cystectomy for muscle-invasive bladder cancer has been reported.[25]

21.5. Comments

Recently, there has been increasing interest in laparoscopic radical cystectomy, and about 400 such cases have been performed all across the world in different centers based on published articles and abstracts. However, these procedures are not free of complications and complications increase if the diversion is performed totally intracorporeally.[17,18]

Menon and colleagues, after acquiring substantial experience in the field of robotic radical prostatectomy, is credited for expanding the horizon of robotic surgery in the field of bladder cancer.[19,20]

Robotic radical cystectomy is a procedure that is currently in developing phase. The basic tenet of this technique is to take advantages of established principles of open surgery and laparoscopic surgery and develop minimal invasive procedure with the benefits of robotic assistance. Various instruments (robotic and laparoscopic), lens, and suture used during RRC are described in Table 21.1. Most of the series (Table 21.2)

Table 21.2. Published reports from the literature.

Reference	Menon[19]	Beecken[22]	Menon[20]	Yohannes[27]	Hemal[21]	Balaji[26]	Dasgupta[28]
Number of cases	14	1	3	2	24	1	5
Number of ports	5–6	Minilaparotomy, 5	5–6	5	5–6	6	5–6
Lymphadenectomy lymphadenectomy	Bilateral extended pelvic lymphadenectomy	Bilateral pelvic lymphadenectomy	Bilateral extended pelvic lymphadenectomy	Bilateral pelvic lymphadenectomy	Bilateral extended pelvic lymphadenectomy		Bilateral pelvic
Operation time (min)	RRC, 140UD, 120 (IC); 168 (ONB)	RRC + UD, 510	RRC, 150, 160,170 UD, 130, 190, 170 150, 250, 100	10 and 12 h	RRC, 110 to 170 UD, 120 to 180	828	390 (median)
Blood loss (cc)	<150	200		435 and 1800	100–300	500 (decrease in Hb 5.3 g)	150 (median)
Surgical margins	Free of tumor infiltration	Negative	Negative	In 1 case perivesical invasion	Free of tumor infiltration	Negative	Negative
Urinary diversion	Ileal Coduit, 2 W-pouch neobladder, 9 Double chimney, 2 T-pouch, 1	UD, Hautmann ileal neobladder; midline incision was extended to exteriorized ileum for ileo–ileal anastomosis	Ileal coduit, 1 W-pouch neobladder, 1 T-pouch, 1	In both cases ileal conduit was reconstructed	Ileal coduit, 4 W-pouch neobladder, 16 Double chimney, 2 T-pouch, 2	Intracor poreal ileal conduit	Ileal conduit, 5
Intraoperative complications or conversion	None	None	None	None	None	Ileus	Port site bleeding

Abbreviations: IC, ileal codiut; ONB, author, please provide definition; RRC, robot-assisted radical cystectomy; UD, urinary diversion.

Table 21.3. Benefits and limitations of robot-assisted radical cystectomy.

Benefits	Limitations
Learning curve for robotic surgery is less steep	Cost
Magnification and three-dimensional vision improve surgical identification and precision	Long-term oncologic outcomes awaited Learning curve of technique, especially
Physiologic hand–eye coordination and elimination operative of hand tremor	lymphadenectomy and creation of neobladder Longer time in the beginning
Endowrist™ technology reproduce the degrees of freedom available in open surgery. This helps in dissection in narrow area, intracorporeal suturing, and in nerve sparing	Abdominal incision for specimen removal and diversion as described in most of the reported series
Decreased blood loss	
Cosmesis	
Less postoperative pain	
Less morbidity	
Shorter hospital stay	
Early recuperation	

described in the literature used between five and six ports and the surgical technique developed by Menon and colleagues.[19]

This technique is performed in three steps, as described earlier, with excellent outcome, though long-term oncological follow-up is awaited. Becken and colleagues described the possibility of intracorporeal reconstruction of orthotopic neobladder in a single case.[22] Later, Balaji and coworkers described the possibility of intracorporeal reconstruction of ileal conduit in a patient.[26] Both procedures required long operative time and a prolonged hospital stay (Table 21.2).

Various series of RRC published in the literature with intraoperative, peri-operative, and postoperative details are illustrated in Table 21.2.

Robotic radical cystectomy and urinary diversion is perhaps the most difficult procedure to perform; however, it is clear that this procedure can be done well, with excellent efficacy and outcome. The technique of RRCP allows precise and rapid removal of the bladder with minimal blood loss, which is translated into minimal morbidity with equivalent success to open surgery. This approach incorporates advantages of minimally invasive and open surgery. Extracorporeal reconstruction of the urinary diversion requires less operative time at this stage of evolution of laparoscopic and robotic instrumentation.

The development of a technique for performing nerve-sparing RRC using the da Vinci® system is also beneficial for sexually active young patients and it is easy to perform in males as the prostate is benign in these patients. The good results in terms of urinary incontinence is achieved due to excellent apical dissection, preservation of puboprostatic ligaments, sphincter urethrae, and good urethral stump complimented by urethra–neobladder anastomosis with robotic assistance. The current benefits and limitations of RRC are described in Table 21.3.

21.6. Conclusion

However, the challenge for the future is to continue to work to distinguish what can be done from what should be done, especially in area of cancer bladder, where two major components (extirpative surgery in the form of radical cystectomy and reconstructive surgery for urinary diversion) of surgery are mandatory. The long-term follow-up with disease-free and overall survival and functional outcome is important. It is also important to have randomized series comparing the procedure with the gold standard open surgery. In the future, with the development of technology, instrumentations, tissue engineering, absorbable bowel stapler, and with further refinement of technique, the entire procedure may be done completely intracorporeally with equal efficiency.

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22
Complications of Robotic Surgery and How to Prevent Them

Scott Van Appledorn and Anthony J. Costello

Robotic surgery has rapidly progressed into the mainstream of modern surgical practice. The da Vinci® Surgical System (Intuitive Surgical Inc., Sunnyvale, CA) has been particularly embraced by the urologic community. Some of the urologic applications include pyeloplasty, cystectomy with diversion, adrenalectomy, pelvic floor reconstruction, nephrectomy, and partial nephrectomy.[1–6] However, the robotic system's largest impact has been in its use for radical prostatectomy. It has been calculated that in 2005, 20% of all radical prostatectomies performed in the United States are performed using a robotic platform, and that number is projected to grow significantly. International usage is also gaining increased acceptance.

Complications are an inherent part of any surgery and the surgeon's goal is to minimize the number of complications. Complication rates are reduced by selecting appropriate candidates for surgery, choosing the best operation for the specific indication, using meticulous technique, and recognizing and treating complications quickly and effectively when they do occur in order to minimize the impact of the problem. A robotic interface may reduce the rate of operative complications because it provides the surgeon with the following advantages: magnified, three-dimensional (3D) vision, digitized hand movements that can filter tremor, and superior maneuverability of robotic instruments. One of the potential disadvantages of the robotic system is that there is no tactile feedback, thus surgeons can not rely on the feel of the tissues to guide the dissection. This also removes the surgeon's ability to manually gauge the appropriate tension required while suturing and knot tying. However, our opinion is that the superior visualization of the operative field allows the surgeon to adopt visual cues, thus replacing the need for tactile cues.

In this chapter, we will discuss complications that can occur during robotic surgery. We have identified specific points where complications can occur and make suggestions to limit them. Patient positioning, anesthetic considerations, robotic setup and port placement, and establishment of pneumoperitoneum will be addressed. Because radical prostatectomy and pyeloplasty are the most common procedures performed using the robotic platform, we will review the reported complications of each and describe techniques for avoiding them. The importance of an experienced operative team as well as the impact of surgeon experience, or the learning curve, are other noteworthy considerations.

22.1. Patient Positioning and Anesthetic Issues

Proper patient positioning on the operating table is essential to allow optimal exposure of the desired operative field, as well as to prevent neuromuscular injuries. This is even more critical if a da Vinci® robotic surgery platform is to be utilized. The patient's position must provide access to the operative site while accommodating the robotic camera and working arms. Once the robot has been docked, there can be no


Figure 22.1. Hand is flexed into a fist over a sponge ball.

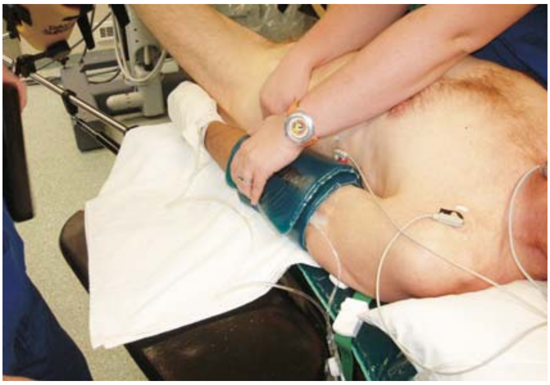
Figure 22.3. Pressure points are adequately padded with gelfoam.

adjustment of the patient's position because the robotic surgical cart is locked in a fixed position adjacent to the patient. This requires that the patient be secured into position so there is no accidental movement during the procedure. This also is problematic for the anesthesiologist, who must carefully arrange intravenous (IV) access and arterial lines (if required) prior to positioning because access will be limited once the robotic portion of the procedure is initiated.[7] For pelvic surgery, the patient is placed in a Trendelenburg position with the lower extremities in lithotomy stirrups. We place a gelfoam mat over the operating table, which provides padding to the pressure points as well as gently adheres to the patient's skin. This assists in maintaining the desired position despite the angle of Trendelenburg. Other surgeons use straps placed over thoracic foam padding to secure the patient's position. Bean bag devices are also used but risk the possibility of unnoticed leakage and deflation while covered by the drapes.[8] The clavicle can be pushed into the brachial plexus if shoulder braces are used to prevent sliding in a steep Trendelenburg position. The elbows are wrapped in gel foam or other padding. The hands are flexed into a fist over a foam squeeze ball and the entire upper extremity is tucked at the patient's side using the bed sheet (Figures 22.1–22.4). This helps prevent injury to the brachial plexus and ulnar nerve. For pelvic surgery, the robotic tower must be positioned between the patient's legs, which are


Figure 22.2. Hand is wrapped with gauze to secure position.


Figure 22.4. The bed sheet is used to secure the upper extremities at the patient's side.

Figure 22.5. Yellowfins stirrups provide stability and padding.

placed in a low lithotomy to allow the robotic arms to reach over them. We use Yellowfins stirrups (Allen Medical, Acton, MA), which provide adequate cushioning of pressure points along with excellent stability (Figure 22.5). There has been a report of leg pain following robotic-assisted laparoscopic prostatectomy (RALP) that was associated with prolonged operative time and stirrup placement.[9] It has been shown in a cadaveric model that hip abduction greater than 30° can strain the obturator nerve enough to cause neural damage.[10] This strain is alleviated with the addition of 45° or more of hip flexion. Therefore, during RALP we attempt to minimize the amount of hip abduction and maximize the degree of flexion that still accommodates the robotic arms.

The same principles of adequate padding of pressure points and avoiding extreme flexion, extension, or torque will help to minimize complications when positioning for transperitoneal renal or adrenal surgery. A subaxillary roll should be placed to prevent excessive traction of the brachial plexus. The surgeon's hand should fit into the axilla above the roll when properly positioned. Severe arm abduction and rotation should also be avoided. The extension of the kidney rest and the flexion of the table over the kidney rest should be used with caution when contemplating potentially lengthy robotic procedures. The kidney rest should be positioned just over the iliac crest to prevent lung splinting and atelectasis. The exact rate of neuropathy due to patient positioning is unknown, however, a survey of urologic institutions revealed a 2.7% rate of neuromuscular injuries.[11] Postoperative injuries to the radial nerve, ulnar nerve, brachial plexus, sciatic nerve, obturator nerve, peroneal nerve, and lateral femoral cutaneous nerves have been reported.[12–14] Reisiger and colleagues recently reported on 7 patients in a series of over 700 who developed rhabdomyolysis after laparoscopic renal surgery. Prolonged positioning in the extended lateral decubitus position with extension of the kidney rest was implicated as a causative factor for this potentially serious complication.[15]

The risk of anesthetic complications related to the pneumoperitoneum during robotic surgery should be similar to laparoscopic surgery. Gas emboli occur very rarely but can cause severe cardiovascular failure and death. It is presumed to occur from rapid insufflation directly into the bloodstream. It will present immediately after establishing pneumoperitoneum. A mill-wheel cardiac murmur, hypoxia, decreased carbon dioxide (CO_2) exhalation, and cyanosis are signs of a gas embolus, and transesophageal echocardiography may confirm the diagnosis. Treatment directives include rapid removal of pneumoperitoneum, hyperventilation with oxygen, placing the patient in the left lateral decubitus and Trendelenburg positions, and potentially aspirating the embolus via a central venous catheter.[16] Most importantly, prevention with proper access technique, as discussed in the next section, is imperative.

Robotic surgeons and their anesthesia team need to understand the physiologic effects of pneumoperitoneum, particularly on the cardiovascular and pulmonary systems. Carbon dioxide is the gas most often used for insufflation due to its high diffusion coefficient.[17] This allows CO_2 to be highly soluble into the bloodstream and minimizes the risk of gas emboli. Carbon dioxide levels are easily measured at the end of exhalation. This allows the anesthesiologist to adjust the ventilator to remove excess CO_2, which prevents hypercarbia and acidosis. The functional residual capacity is impaired during laparoscopy due to insufflation pressure and patient positioning. This decreases pulmonary compliance and results in ventilation–perfusion mismatching, which can also lead to hypercarbia and acidosis. Increasing the minute volume may correct this, however, patients with pulmonary dysfunction may present a particular challenge. This illustrates the need for careful selection of patients undergoing robotic surgery as well as screening for pulmonary disease.

The physiologic effects of laparoscopy/robotic surgery on the cardiovascular system can also be problematic. The increased abdominal pressure causes compression of the vena cava and decreased preload volume delivered to the right atrium. There is also increased pressure on the aorta and heightened sympathetic tone. This causes increased cardiac afterload and a reduction of cardiac output. This can be minimized preoperatively by intravascular volume expansion. At our institution, patients for RALP are generally given at least 1 L of crystalloid prior to establishing pneumoperitoneum. Cardiac arrhythmias can occur in up to 27% of laparoscopic procedures, commonly due to increased vagal tone and hypercarbia.[18] Treatment includes hyperventilation, decreasing CO_2 insufflation pressures, and antiarrhythmic medications. The surgeon generally can minimize complications of positioning and anesthesia by collaborating with a dedicated team that is well versed and knowledgeable of the specific issues related to laparoscopy and robotics. Screening operative candidates for pulmonary and cardiovascular disease will help reduce intraoperative complications caused by the effects of pneumoperitoneum.

22.2. Complications of Access and Port Placement

Although robotic-assisted surgery was originally designed for use as an open technique, it has been adapted primarily for laparoscopic surgery.[19] The robotic surgeon must understand the potential complications of establishing pneumoperitoneum and placing trocars. The da Vinci® robot is a relatively immobile and bulky structure and consideration must be given to proper port location. This may avoid the clashing of instruments and ensure that the instruments reach the operative field.

There are many safe and effective methods of obtaining peritoneal access. Individual surgeon preference leads to development of a technique that is comfortable and reproducible. It may be advantageous to know more than one technique. A Veress needle can initiate pneumoperitoneum quickly, though it is a blind procedure relying on the feel of the needle popping into the peritoneum. The reported rates of vascular and bowel injuries vary from 0.03% to 0.3%.[20] If the Veress needle is used, it is important to remember the location of the aorta and iliac vessels near the umbilicus, which can be injured with overzealous needle entry. The needle should be aspirated to ensure no return of visceral fluid, followed by injection of saline. The drop test will confirm that saline flows freely into the peritoneum. If there is any doubt the sequence should be repeated or the needle replaced. Once insufflation is started, a low intraperitoneal pressure suggests correct needle placement. After insufflation is completed, the initial cannula can be placed blindly or with an optical access trocar. The optical access trocar allows visualization of tissue planes and may prevent bowel perforation. A series of 1283 patients using this technique resulted in one bowel and three vascular injuries.[21]

An open or Hasson technique may reduce the amount of injuries by allowing direct visual placement of cannulas into the peritoneum. However, it can be cumbersome and create leakage of insufflant during the procedure. This technique also may potentially result in visceral and vascular injury. A large series of over 10,000 cases reported a complication rate of 0.2%, including six bowel injuries.[22] We have reported a modified Hasson technique which allows safe and rapid placement of the initial camera trocar. A 1- to 2-cm vertical incision is made superior to the umbilicus. The subcutaneous adipose is dissected from the fascia. The umbilicus is grasped and raised with an Aliss clamp and the fascia is incised in the midline. After additional blunt dissection, a finger is then used to navigate an entry to the peritoneum. This technique is fast, results in minimal leakage, and no access-related complications have been detected to date.[23]

Once access has been established, the remaining trocars can be placed. All secondary ports should be placed under direct vision. The skin can be illuminated with the camera light to avoid injuring abdominal vessels. The skin incision should be long enough to freely accommodate the trocar, which will minimize the amount of downward force needed for insertion into the peritoneum. Nonbladed trocars may minimize vascular injuries and create smaller fascial defects, which may reduce port site hernias.[24] The location of port placement depends upon the type of surgery performed and varies with surgeon preference. The location of the epigastric vessels should always be considered during trocar insertion. These vessels are not always visualized, but their location in the lateral part of the rectus sheath must be recognized. If an epigastric vessel injury does occur, a full thickness suture can often stop the hemorrhage. When using the robotic platform it is important to consider the patient's body habitus and the number of ports needed. While landmarks such as the umbilicus, pubis, xyphoid process, and the costal margin are useful for port placement, the surgeon must be cognizant of extremes of height and weight which may alter the standard port positions. The robotic arms have a working length of 25 cm and complications can result from placing their ports too near or too far from the operative field. The working arm ports should also be placed between 8 to 10 cm from the camera to avoid clashing of the instruments.

22.3. Complications of Robotic-Assisted Laparoscopic Prostatectomy

Very few complications exist that are specific to robotic surgery. A presumption is often made that advantages of the minimally invasive approach, such as decreased blood loss and pain, shorter hospital stay and return to ambulation and activity, would improve the complication rate compared to open surgery. However, complex procedures also require a learning curve, and complications may be increased when undertaking a new technique with longer operative times. Although the field of robotics is rapidly growing, there are relatively few centers reporting large series to analyze complication rates. It is a challenge to compare and analyze complications of any surgical technique because many reported series do not record complications in a prospective and uniform manner. The Clavien system of classifying complications by grade has been adopted by some authors, but it is often interpreted differently by authors and suffers from subjective data input.[25] For example, is the conversion to open surgery a complication or does it represent a judicious decision to safely complete an operation? Another consideration is that many low-grade complications may go unrecognized because robotic surgery has been performed as an outpatient procedure and follow-up might be performed at a separate facility. Only prospective randomized trials can adequately compare complication rates between different techniques or surgeons, and this is rarely done. Robotic-assisted laparoscopic prostatectomy (RALP) is the most commonly performed robotic surgery. An estimated 2500 cases were performed in the United States in 2004.[26] The reported overall complication rate from this procedure is 1% to 34% (Patel VR, personal communication)[28–30] Specific complications are listed in Table 22.1.

The rate of rectal injury during RALP is 0% to 0.9% in large series. This is often due to severe inflammation and fibrosis, which has obscured the tissue plane that exists between the rectum and the prostate. Alternatively, if the posterior bladder neck is divided too distally or incompletely, the dissection may course into the prostate itself. The dissection potentially could proceed posteriorly distal to the vasa and seminal vesicles, and failure to identify these key anatomical landmarks may cause rectal injury. If an injury does occur, a primary closure of the edges in two layers is acceptable in the absence of a sizeable defect or a large volume of fecal contamination. The robotic system will allow precise suturing, and the integrity of the closure can be confirmed under direct vision after instilling saline or air into the rectum. The operative field should be copiously irrigated and well drained after the procedure. The two rectal injuries that occurred at our institution were repaired in this manner without any significant postoperative morbidity. Consultation with a general surgeon is encouraged. Injury to other intestinal segments bowel also has been reported in 0% to 0.7% of series. This can be related to access difficulty (i.e., due to trocar injury), adhesions from previous abdominal surgery or infection, or due to

Table 22.1. Robotic radical prostatectomy series.

Complication	Ohio State University[48]	Pennsylvania State University[48]	University of California, Irvine[48]	Costello[30]	Vattikuti (2004)	Bentas[29]
N	500	330	300	122	1100	40
Rectal injury	2	3	1	1	2	0
Deep venous thrombosis	0	1	1	0	1	1
Pulmonary embolus	0	0	5	0		2
Hemorrhage	2	0	1	1	4	2
Myocardial infarction	1	0	0	0		
Transfusion	1	0	2	1		
Clot retention	8	9	2	1	1	
Anastomosis disruption	17	0	4	6		4
Urinoma	0	0	1	0		
Ileus	2	8	1	1		
Wound infection	0	2	0	0	1	
Acute urinary retention	5	5	3	2	21	
Conversion to open surgery						
Bowel injury, not rectal				0	2	
Bronchial edema				0	1	
Anastomotic stricture	1	3	1	5	9	
Meatal/fossa strcture	0	6	10	0	1	
Incisional hernia	3	1	2	0	2	
Incarcerated inguinal hernia	0	1	0	0		
Lymphocele	0	0	2	0		

electrocautery injury. Monopolar electrocautery should be used with extreme caution because the thermal energy can unintentionally spread to surrounding viscera. These injuries may go unnoticed and have a delayed presentation with fever and peritonitis. If a bowel injury is recognized intraoperatively, it may be primarily repaired though the injury may require debridement to ensure the apposition of healthy wound edges.

The combination of pelvic cancer surgery, pneumoperitoneum, and prolonged lithotomy position places patients at an increased risk for thromboembolic events following RALP. The reported rates of pulmonary embolism and/or deep venous thrombosis are 0% to 7.5% in large series (Patel VR, personal communication).[28–30] This can be a life-threatening event that requires immediate diagnosis and treatment. There remains some debate as to the best prophylaxis. The American College of Chest Physicians recommends subcutaneous heparinoids as firstline prophylaxis for robotic radical prostatectomy (RRP). Others have relied upon compression stockings, sequential compression devices, and early ambulation to limit the number of thromboembolic events.[31] Our protocol uses unfractionated heparin in the peri-operative period. To date, we have not experienced any thromboembolic events. The clinical effect this regimen has on hemorrhage or postoperative oozing is unknown, but it is not thought to be a significant problem.

Calculating the amount of hemorrhage is difficult because there are no uniform reporting criteria. The previously referenced series report a 0% to 5% rate of hemorrhage with a transfusion rate of 0% to 1.2%. The epigastric vessels can be injured during trocar placement and during dissection of the bladder from the anterior abdominal wall. The dorsal venous complex (DVC) is another common site of bleeding during RALP. This can be controlled with an endovascular stapler or by suture ligature.[32] Persistent bleeding from this area prior to dissection of the bladder neck can be controlled by packing a small gauze over the injury or temporarily increasing the intraabdominal pressure to 20 mm Hg. Another effective technique is to proceed with the division of the bladder neck and elevate the base of the prostate via a percutaneous suture through the eye holes of the Foley catheter. This will often tamponade even vigorous bleeding from the DVC and allow the operation to continue without troublesome bleeding. If the hemorrhage from the DVC occurs after division of the apex, the surgeon may employ several different maneuvers to control it. Along with a temporary increase in intraabdominal pressure, a Foley catheter balloon can be inflated and gentle traction applied over the DVC to decrease the rate of bleeding. If the bleeding is moderate and the surgeon is facile with the urethrovesical anastomosis, completion of the anastomosis with incorporation of the bleeding tissue may control it. The prostate pedicles are another common area of hemorrhage. There are many ways to control this, including use of laparoscopic vascular clamps, locking clips, tissue sealants, suturing, and monopolar or bipolar electrocautery. An important consideration is the spread of thermal energy that can unintentionally damage surrounding nerves.[33] Numerous techniques have been described to avoid and repair hemorrhage, and knowledge of these techniques may prevent the complication rates of transfusion and hematoma formation.

Postoperative ileus following RALP is a rare event that can prolong a patient's hospital course and cause severe discomfort. The reported rate of ileus following RALP is 0.7% to 2.4% (Patel VR, personal communication).[28–30] Bhandari and colleagues noted that 5 of 300 patients who had an RALP performed by surgeons experienced beyond the initial learning curve developed an ileus. The authors related postoperative ileus to either leakage from the urethrovesical anastomosis or pelvic hematoma. This may be a drawback of the transperitoneal technique, because urine and blood can come into direct contact with the bowel. Extraperitoneal RALP has been described but it is unknown the exact impact this has upon the rate of ileus. Gettman and colleagues reported no perioperative complications in a small series of four RALPs using the extraperitoneal approach.[34] Brown and coworkers recently compared transperitoneal to extraperitoneal laparoscopic radical prostatectomy. One of their observations was that the extraperitoneal technique led to an increased rate of anastomotic leakage, but none of these patients developed an ileus. Two of three patients who developed an ileus with the transperitoneal leak also had anastomotic leakage.[35] Our experience is that anastomotic leakage after transperitoneal RALP not only causes ileus, but the leakage may persist for a long duration. Therefore, a watertight anastomosis is essential for minimizing complications. We use a similar method of anastomosis as described by Van Velthoven and colleagues, which utilizes a running suture with a single knot.[36] Adequate tissue must be taken with each suture bite to prevent the suture from inadvertently pulling through the tissue. We have found that loops of suture that were not tautly drawn were the likely cause of leakage. To prevent this we have used two different techniques: One technique is to pull both ends of the suture taut after each throw of the suture to ensure no loosening of the previously thrown sutures. Tension on the sutures should be placed anteriorly rather than cranially to minimize the chance of pulling them out. Alternatively, one side of the suture can be completed and the suture then kept taut by an assistant's laparoscopic needle driver. The other half of the anastomosis is then completed without concern of the previous half loosening. Ball and associates have described a similar method of prevention of urinary extravasation and loosening of the suture by using a Lapra-Ty clip (Ethicon, Cincinnati, OH) to secure one side of the suture taut.[37]

22.4. Robotic Pyeloplasty

The da Vinci® Surgical System is an ideal instrument to treat ureteropelvic junction obstruction due to its minimally invasive nature, as well as the precision it affords with intracorporal suturing. There are few large series of robotic pyeloplasties because this is a relatively rare operation and new technique. Selected series are presented in Table 22.2.[38–43] Mendez-Torres and colleagues reported only one peri-operative complication in their series, which was a ureteral stent migration and repositioning. Siddiq and coworkers reported three postoperative complications. One patient had a postoperative fever, one patient had a urinary leak which resolved with Foley catheter drainage of the bladder, and the third patient developed an umbilical hernia. In a combined series of 35 patients, Palese and associates reported four postoperative complications including urinary tract infection (UTI, 1),

Table 22.2. Robotic pyeloplasty series.

Mendez-Torres[43]	Peschel[40]	Patel[32]	Bentas[39]	Siddiq[41]	Palese[42]	
N	49	50	11	26	35	32
Estimated blood loss (mL)	<45	40	minimal	69	74	52
Intraoperative complications	0	0	0	0	0	0
Postoperative complications	1	1	1	3	4	1

pyelonephritis (2), and gluteal compartment syndrome requiring fasciotomy (1). Peschel and colleagues reported only one complication in a series of 49 patients. A patient developed a urinary leak from the renal pelvis that was away from the anastomosis, and this required an open repair. All of these series reported high success rates of the operation. For comparative purposes a large series of 100 nonrobotic laparoscopic pyeloplasties had a 13% complication rate.[44] The most significant complications were urinary ascites (2), urinoma (1), and lower pole venous bleeding (1). There is not enough data to generate strong conclusions regarding the rate of complications with robotic pyeloplasty, but initial reports seem promising.

22.5. Mastering the Robotic Surgical System

The da Vinci® robotic system has allowed many nonlaparoscopic surgeons the ability to perform minimally invasive procedures. As a result, many patients have benefited from robotic surgery who might otherwise have undergone an open operation. It is generally acknowledged that nonrobotic laparoscopy can be technically demanding and has a prolonged learning curve, particularly for complex procedures. Some have estimated that laparoscopic radical prostatectomy has a learning curve of 40 to 80 cases. Trablusi and Guilloneau reported continued improvement in blood loss, operative time, and open conversions after 50 cases, and they continue to reduce operative times after 300 cases.[45] In contrast, the learning curve for RALP for laparoscopically naïve surgeons has been estimated to be approximately 20 cases.[9] It is unclear what role robotic experience plays in reducing complications. The Vattikutti Institute group determined that they had a similar complication rate in their first 200 cases compared to their second 200 cases and determined that the learning curve is complete by 200 cases.[28] This implies an inherent complication risk with any surgery, despite technical mastery of the procedure and the surgical system. Another interesting concept is whether the use of the surgical system decreases the rate of complications compared to open series. This is difficult to establish due to the variability of surgeon skill, patient co-morbidity, extent of disease, and other factors. However, Tewari and colleagues have shown from a single institution that RALP significantly reduced blood loss, catheterization days, and complications when compared to open radical prostatectomy. An earlier return of continence and erections was also reported.[46]

Another potential risk of robotic surgery that may affect the complication rate is technical malfunction of the equipment. Fortunately this is a rare occurrence. A general surgery series of 211 cases reported a 4% rate of technical complications. These included minor problems such as hook cautery dislodgement and trocar displacement. However, three of the cases experienced system malfunctions, and two cases required conversion to standard laparoscopy. This could be problematic for surgeons not experienced with that technique.[47] The University of California, Irvine (UCI), group has reported four (2%) delays due to software problems and one conversion to conventional laparoscopy due to power outage.[26] This has been a minor problem at our institution. On one occasion the surgical system froze during a procedure, which required 45 min until the problem was corrected. It is recommended that a representative from Intuitive Surgical Inc. be present during the initial experience at an institution to assist the operating room team with mechanical issues. Eventually most technical issues can be handled over the phone. This stresses the importance that the whole operating team be facile with the robotic system, and not just the surgeon. The anesthesiologist, surgical assistant, scrub nurse, circulator, and technical support personnel all play vital roles toward preventing complications during any robotic procedures. Their experience and competence will reflect upon the patient's outcome.

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23

Applications of Robotics in Pediatric Urologic Surgery

Craig A. Peters

The availability of practical, clinically approved robotic surgical assist systems for laparoscopy, the da Vinci® (Intuitive Surgical Inc., Sunnyvale, CA) and Zeus® (Computer Motion, Santa Barbara, CA) systems, opened a door that was only ajar for reconstructive laparoscopy in pediatric urology.[1] The technology is novel and expensive, yet the initial results and experience justify an enthusiastic continuance of its development and application in pediatric surgical practice. With increasing familiarity with its potential, its applications have broadened to more than a dozen types of procedures. This chapter will review the current use of robotic-assisted procedures in pediatric urological practice, and provide an early assessment of the strengths and limitations and speculation as to the future directions.

The principle advantages of the most commonly used system, the da Vinci® system, is in the provision of precise and delicate movements in a laparoscopic platform under exceptional visual control. The need to compensate for laparoscopic paradoxical movement is no longer present and the precision with which movements may be made is clearly better than conventional laparoscopy. While it might be said that some laparoscopic surgeons are able to suture delicate tissues equally well, there are very few pediatric urologists who have developed those skills. The application of laparoscopic pyeloplasty 10 years after its description by a very limited number of surgeons is evidence that difficulty. With the ability to scale movement and filter tremor, the surgical precision is excellent. What its limits might be remain to be determined, but studies have been published reporting its use in vasovasostomy using 9-0 and 10-0 suture. The visual guidance in three dimensions provides a level of enhancement over laparoscopy that must be experienced. Two-dimensional (2D) imaging is workable, but once the clarity and richness of three-dimensional (3D) imaging are experienced in the surgical field, it is difficult to compromise with only two dimensions. With this enhanced visualization is likely to come enhanced surgical capacity and outcomes, although this remains to be proven.

There are several challenges in the child that must be understood and anticipated in the application of robotic assistance. The wide range in size of the patients requiring surgery makes it difficult to have uniform equipment or setup procedure for these systems and a flexible approach is needed. Similarly, the anatomic orientation of the kidney, for example, may be different and require modification of port site placement. The size of the cannulae and instruments appear very large in the context of small children, yet it should be recalled that early efforts in pediatric laparoscopy were limited to 10-mm cannulae and while they were large, it did not appear to make a large difference in the outcomes of the patients. Similarly, there is a natural evolution of technologies and already we have 5-mm instruments for the da Vinci® system and it would be possible to reduce these further if the need appears. The camera port remains large at 12 mm and this is best hidden in the umbilicus, rather than in the abdomen. It becomes unnoticeable after one to two months. The working ports remain noticeable for several months but eventually fade and leave minimal scarring. There is no information on the psychological impact of these small scars, but it is important to recognize that scar size is not the principle rational for laparoscopy.

The smaller working space in the child requires consideration in port placement and operative strategy. With the robotic cannulae, there is a specific amount of the cannula that must be within the abdominal cavity to permit the point of no movement (the virtual center) to be at the abdominal all. Even with 5-mm instruments, this is a long distance and puts the tip of the cannula closer to the working area. With the working instruments in place, the articulating segment must be wholly out of the cannula to prevent restriction of movement. This puts the tip even further towards the working area. In the small child this may be past the point where the instrument needs to be used. Therefore, the port entry sites must be further away from the actual operative area. For bladder or pelvic procedures, this means higher in the abdomen; for renal procedures, they must be nearly to the midline. This positional adjustment needs to be done without sacrificing the symmetric arrangement of the port around the endoscope. In practical terms this is an issue in children under nine months. Similarly, the endoscope cannula, which does not have a marked virtual center, cannot be placed too far into the abdomen or the field of vision will be very limited. During procedures, even with these adjustments, it can be found that as the work moves away from the midpoint between the instruments, the proximity of the tip of the cannula becomes a limiting factor. Often this is during mobilization of the colon for renal exposure. In these cases, it is useful to use the instruments in a crossed fashion so that the holding instrument is the one in the lower quadrant and very close to the action, but it is moved upward, retracting the tissue, and the upper instrument crosses it, performing dissection. This way, both instruments are moving away from their respective cannulae.

Handling tissues requires recognition of the forces generated by the robotic instruments and caution must be taken to avoid directly grasping any functionally important structures directly. Lifting by the adventitia or scooping will reduce the chance of crush injury. Traction sutures are very useful when carefully placed to provide exposure and stability while removing tissue from areas with pooled blood or urine. A well-placed traction stitch will also facilitate access to particular areas, such as the ureterovesical junction. Any traction stitch must be positioned so as to avoid entanglement with the other instruments and sutures. It may be placed through the abdominal wall and brought back out, permitting adjustment of tension. A traction stitch may be tied to another structure, often the internal abdominal wall, but this limits the tension adjustment. A simple short segment of suture tied to the tissue can be used to allow movement without crushing during a procedure, as well.

A final concern regarding use of the da Vinci® robotic system in children is the very large relative size of the device to the child. It may be difficult to even see, let alone access the patient when the robot is engaged. Both the surgical and anesthesia teams must be aware of this and have clearly established paths of access to the patient established before the procedure commences. This facilitates periodic assessment of the patient and the ability to rapidly get to the patient if the need should arise. Consideration for emergency procedures, such as rapid undocking, must also be made between the teams.

23.1. Pediatric Urologic Procedures

The principle procedures for which the da Vinci® system has been used include pyeloplasty, vesicoureteral reflux correction, partial nephrectomy, and nephrectomy. Several other procedures have been performed and reported in limited numbers. The overall experience remains very limited and few comparative studies have been published to date. Most procedures have been previously performed using conventional laparoscopic methods, yet few were used with any frequency, and only by a small group of persistent, perhaps obstinate, surgeons. The robotic device is likely to permit more surgeons to use laparoscopic methods for pediatric urology due to the enhancement of manipulation, particularly delicate suturing; this remains to be seen. While the technical aspects of the major procedures are very similar to the conventional laparoscopic methods, several specific points should be borne in mind.

23.1.1. Pyeloplasty

In many ways, pyeloplasty is the ideal procedure for the da Vinci® system as its success depends upon precise delicate suturing. The tissue trauma is largely from access rather than the actual procedure, making it the ideal laparoscopically performed procedure. Indications are identical to those for open surgery.

23.1.1.1. Setup

The patient is placed on a wedge of 30° and strapped to the table. The table is rotated to have the abdomen flat for port placement, then is rotated in the opposite direction to place the patient at a 60° angle with the ipsilateral flank elevated to provide exposure. The robot is brought in at about a 30° angle over the patient's ipsilateral shoulder along a line from the umbilicus to the kidney.

23.1.1.2. Port Placement

The first port is the endoscopic 12-mm port in the umbilicus with a preplaced fascial stitch for later closure. Two working ports are placed; the first in the midline between the xyphoid and umbilicus, and the second in the mid-clavicular line between the umbilicus and pubis. This port should be moved more medially if the renal pelvis is very large or in smaller children. Both are placed under direct vision using the sharp trocar and a preplaced fascial stitch.

23.1.1.3. Exposure

The ureteropelvic junction (UPJ) is exposed in one of two ways. On the left side in a young patient, the dilated pelvis and ureter are often visible through the mesentery and this is incised over the UPJ, which is mobilized and lifted upward. Care is taken to avoid the mesenteric vessels, which are readily visible. When the pelvis is not visible, particularly in older children with more retroperitoneal fat, the colon is mobilized along the line of Toldt and dropped medially, facilitated by gravity and the positioning of the patient. This is the best means of exposure on the right side in nearly all cases. The renal pelvis is lifted with a hitch stitch passed through the abdominal wall or sutured to the anterior–lateral abdominal wall. This exposes the UPJ, stabilizes it, and lifts it above the pool of urine and blood that develops after incising the pelvis (Figure 23.1).

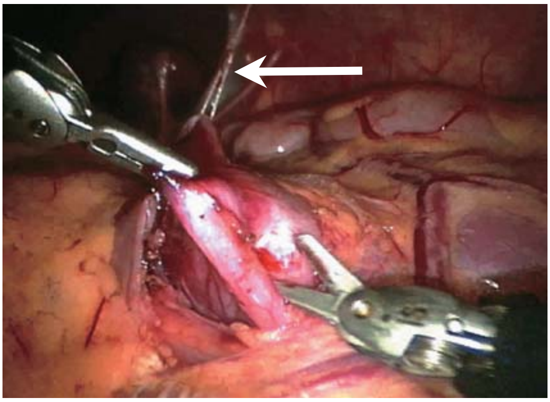

Figure 23.1. Appearance of an obstructed renal pelvis with a hitch stitch (*white arrow*) lifting and stabilizing it while the pyelotomy is made.

23.1.1.4. Procedural Steps

The actual procedure begins with the pyelotomy performed along a line that slopes from lateral to medial from the inferior to midportion of the pelvis. This will be the line of re-anastomosis. The segment of pelvis attached to the UPJ is used as the handle for manipulating the UPJ during the first part of the procedure to avoid crushing the proximal ureter. The ureter is spatulated on its lateral aspect for about 1.5 cm by incising through the UPJ. Often the stenotic segment is readily apparent. If a crossing vessel is apparently the cause of the obstruction, resection of the UPJ is nevertheless recommended and spatulation is performed, along with transposition of the ureter relative to the vessel. Anastomosis is begun with a vertex suture, usually an absorbable monofilament, although some surgeons would prefer a braided absorbable suture. The dependent most wall of the anastomosis is performed with a running suture up to the top of the ureter to be preserved. Interrupted sutures may be used as well, but this reduces the surgical efficiency of the procedure. Near the completion of the back wall suturing, the segment of renal pelvis and UPJ that have served as a handle are removed.

A double-J ureteral stent is placed to provide temporary drainage of the kidney. This is inserted by passing a 14-gauge angiocatheter through the abdominal wall, removing the needle, passing a 0.25″ guide wire through this and into the ureter. It is loaded with a double-J stent of appropriate size (3.8 Fr up to age two years; 4.5 Fr over age two years). The stent is passed down the ureter until the proximal J is at the level of the pelvis. The wire is removed and the J placed in the pelvis. The anterior wall of the anastomosis is competed.

23.1.1.5. Completion

The hitch stitch is cut and removed and the peritoneum is sewn over the pelvis if a transmesenteric approach has been employed. Otherwise the colon is allowed to fall back over the kidney.

Ports are removed under vision, the pneumoperitoneum is evacuated, and the preplaced fascial stitches are tied. A subcutaneous and subcuticular skin closure is performed and local anesthetic is instilled.

The bladder catheter is left in place overnight. Patients are allowed to move and eat as tolerated. Most are ready for discharge on the next day, while some will stay for a second night.

23.1.1.5. Outcomes

There are limited numbers of reports of robotically assisted pyeloplasty in children, but to date, results have been comparable to laparoscopic pyeloplasty and close to open in terms of both efficacy and efficiency.[2–4] There are few reports of complications or the need for conversion. Both transperitoneal and retroperitoneal approaches have been used. In the author's comparative series, the efficacy was equivalent to that of open surgery with only one need for re-operation out of 33 cases.[4] In this one case, which was the only one performed retroperitoneally, a crossing vessel was not detected. The patient was then re-operated transperitoneally with robotic assistance with a successful result. This is not to suggest that retroperitoneal access is not satisfactory, as Olsen's report clearly shows it to be effective, but it may require careful inspection for this unusual etiology.[3] There is clearly a limitation in space that requires very careful port placement. It is also unclear if the advantages seen with transperitoneal access, that is, shorter hospital stay and less narcotics, are similar with retroperitoneal access.

23.1.2. Antireflux Surgery

23.1.2.1. Extravesical

23.1.2.1.1. Setup

Patients are prepped in the supine position, with a bladder catheter placed in a sterile fashion to permit filling and draining during the procedure. The patients heels are at the end of the bed and the robot is positioned such that it is brought in from below.

23.1.2.1.2. Instrumentation

Instrumentation needed for the procedure includes: 5-mm hook cautery; 5-mm Maryland dissector; 5-mm needle holder; and 5-mm scissor.

23.1.2.1.3. Port Placement

An umbilical port is placed for the 12-mm camera and two working ports are placed at the level of the umbilicus in the midclavicular line (Figure 23.2) They are placed in the same manner as described above.

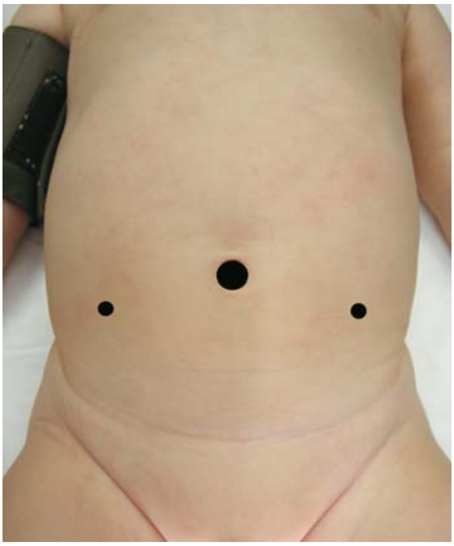

Figure 23.2. Port site placement for extravesical antireflux procedure. The camera port is in the umbilicus.

23.1.2.1.4. Exposure

The ureter is exposed by incising the peritoneum transversely anterior to the uterus in girls and the vas deferens in boys. The course of the ureter is determined by visualizing it cephalad to the uterus along the pelvic sidewall. Just at the level of the ureter entering the bladder, the ureter can be seen by blunt and cautery dissection, with care taken to avoid cautery on the ureter itself. This is done by lifting the surrounding tissues and cauterizing with the hook cautery. Once the ureter is seen, it can be lifted upward and the surrounding tissue bluntly swept away. More attached tissues are cut with cautery, as are the few vessels near the ureter. A total of about 5 cm of ureter is mobilized in this manner to provide enough room to create a tunnel and avoid kinking.

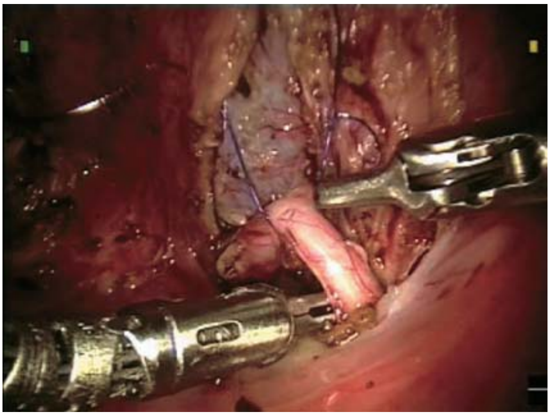

Figure 23.3. View of the posterior aspect of the bladder after incision of the detrusor wall and exposure of the mucosa. The ureter has been mobilized and will be placed within the trough, which will be closed over it to create the antireflux mechanism.

23.1.2.1.4. Procedural Steps

Once the ureter is mobilized, the tunnel is marked with the bladder slightly filled (about 30 cc). A hitch stitch is then placed to lift the back wall of the bladder and stabilize it. This is done by passing a suture through the abdominal wall, then through the bladder above the site of the tunnel and back out the abdominal wall, where the correct amount of tension can be applied. If the patient has too thick an abdominal wall, the suture may be tied within the pelvis.

The detrusor tunnel is created by incising the muscle fibers with electrocautery with the bladder filled with from 30 to 60 cc of saline. This should maintain the exposure and provide enough tension to cause the muscle fibers to separate as they are cut, revealing the underlying mucosa. This should not be cut, but if a small puncture occurs, it can be readily closed with a 5-0 chromic suture. Some of the muscle is lifted off the mucosa to create flaps for the later closure. It is best to start at the cephalad part of the tunnel and work downward toward the hiatus, where it can be slightly harder to find the proper plane (Figure 23.3) At the hiatus, the incision is made in a V around the ureter, but not circumferentially. This might limit the amount of nerve injury that is thought to be the basis for postoperative retention in bilateral cases.

Once the detrusor tunnel is completed, the muscle flaps are brought around the ureter using interrupted 4-0 or 3-0 Vicryl sutures (depending upon age). The most efficient way seems to be to initially place the most cephalad suture, which holds the ureter within the tunnel, and then each of the subsequent stitches can be placed with the muscular edges together. This can be a little problematic if the more proximal ureter obscures the tunnel where the suturing is needed. Alternatively, the tunnel can be closed from the bottom up, but this requires passing the needle under the ureter for each stitch. Each stitch is also under tension when tied. A total of five or six stitches is usually sufficient to create a tunnel of 3-cm length.

23.1.2.1.5. Completion

The bladder is decompressed and the ureter checked for kinking or tightness. The peritoneum is closed with a running 4-0 Vicryl suture. The pneumoperitoneum is evacuated after the ports are removed under direct vision. Fascial sutures are closed and completion is as previously described.

The bladder catheter is usually removed, unless there is concern about leakage at the tunnels due to mucosal injury. Patients are usually ready to leave within 24 hours.

23.1.2.1.6. Outcomes

We have reported on the initial experience of extravesical antireflux surgery using robotic assistance with over 30 cases. The overall results are comparable to open surgery after the initial learning phase. While success was about 80% in the first 10 patients, the subsequent results have been 100% successful for routine cases.[5] There have been no conversions. In the most recent patients, no bladder catheter was used postoperatively. Hospital stay was shorter and postoperative narcotic use was decreased. Hospital stay can be a very subjective parameter, but discharge was largely parent driven, based upon comfort level with the child's home care. Just as it is possible to train parents to take care of patients with day-surgery reimplantation, so it would be possible to do so with laparoscopic procedures. Whether this is really a priority is unclear.

23.1.2.2. Intravesical

23.1.2.2.1. Setup

This is identical to an extravesical approach, except that the bladder is filled with enough saline to make it palpable to a point halfway to the umbilicus.

23.1.2.2.2. Instrumentation

Instrumentation needed for the procedure includes: 5-mm hook cautery; 5-mm Maryland dissector; 5-mm needle holder; and 5-mm scissor.

23.1.2.2.3. Port Placement

This is the most challenging aspect of this procedure, and if this is not accomplished efficiently, the remainder of the case will be problematic. The essential components are to gain access into the bladder and ensure that the bladder wall will remain around the cannula and not leak. The same suture is used to provide closure postoperatively. In a thin patient, this can usually be achieved easily by dissecting down to the bladder wall through a small midline incision for the 12-mm camera port. A purse-string suture is then placed and through this and the cannula placed, either sharply or by using a radially dilating sheath. The port is midway between the bladder and umbilicus. Working ports are placed at a similar level lateral to the midline, depending upon how much bladder distention has been achieved with filling. Once these three ports are in place, the saline is evacuated by insufflating with carbon dioxide (CO_2) and opening the bladder catheter. The catheter is left in place without a balloon and used for suction and irrigation during the procedure.

23.1.2.2.4. Exposure

Once the ports are placed, the view of the trigone is excellent. Each ureter is mobilized by placing a 5-cm segment of 5 Fr feeding tube into the ureter and suturing it with a 4-0 Vicryl suture. This is used as the handle to manipulate the ureter without direct contact.

23.1.2.2.5. Procedural Steps

The mucosa is incised circumferentially with the hook cautery or the cautery shears and the ureter is mobilized by progressive circumferential dissection using both sharp and blunt methods. This is done just as in an open procedure. Once enough ureter is mobilized about 5 to 6 cm, the other side is similarly mobilized. Each ureteral hiatus is reduced with one or two Vicryl sutures and then the mucosal flaps are created around the hiatus. The tunnels are created by sharp and blunt dissection, in a cross-trigonal direction. With the articulated instruments, the scissor can be positioned perfectly parallel to the trigone, facilitating this maneuver. A small opening in the mucosa is cut at the end of the tunnel for the ureteral meatus. The ureters are then brought through the tunnels, which may be confluent, and anastomosed using three anchoring stitches of 4-0 Monocryl in the muscle of the bladder, and two or three 5-0 Monocryl sutures in the mucosa. The feeding tubes are removed.

23.1.2.2.6. Completion

The cannulae are removed and the purse-string sutures tied to close the bladder. The fascial defects are closed with figure-of-eight sutures and the skin closed over this after placement of local anesthetic.

The bladder catheter is left in place for one or two days, depending upon the patient's recovery, and the patient is discharged after voiding.

23.1.2.2.7. Outcomes

There is only one published report of transvesical reimplantation using robotic assistance, and this is an early experience.[6] Results from freehand laparoscopic intravesical reimplantation have been good for a limited number of surgeons.[7] Results are somewhat mixed from a success standpoint, and some of the early cases have persistent reflux. The hospital stay seems to be less, but one patient did have a leak requiring longer stay with a catheter. As the technique evolves, these issues will need to be addressed. If extravesical bilateral antireflux surgery can be shown to have a minimal risk of urinary retention in contrast to open surgery, then the need for intravesical reimplantation may be limited. The utility of developing techniques for intravesical access and robotically assisted procedures, however, could expand to other procedures such as ureterocele excision and bladder neck reconstruction.

23.1.3. Renal Ablative Surgery

23.1.3.1. Nephrectomy

23.1.3.1.1 Setup

Patients are positioned in the same was as for pyeloplasty to permit adequate exposure of the kidney. A catheter is placed in the bladder.

23.1.3.1.2. Instrumentation

Instrumentation needed for the procedure includes: 5-mm hook cautery; 5-mm Maryland dissector; 5-mm needle driver; and 5-mm scissor.

23.1.3.1.3. Port Placement

The camera port is the umbilicus, as most of these cases are performed transperitoneally. Secondary ports are in the ipsilateral upper abdomen in the midline and in the ipsilateral lower quadrant at the mid-clavicular line.

23.1.3.1.4. Exposure

For both right and left kidneys, the colon is reflected medially to reveal the kidney and the hilum. On the right, a liver retractor can be useful to better expose the hilum, but it is not essential. This obviously requires a fourth port, which is placed on the opposite side between the umbilicus and midline port.

23.1.3.1.5. Procedural Steps

Following exposure of the kidney, dissection aims at identifying the ureter and tracking it up towards the hilum. Identification of the renal vessels is the key step and usually the vein is seen first anteriorly. Just below this is the artery, which is ligated first when possible. Either suture ligation or clips being placed using a standard laparoscopic clip applier are used to control the vessels. Care is taken to avoid dissecting the vessels too close to the kidney, as this will tend to control branches, rather than the main vessels. It is important to separate the vessels and ligate individually. It is usually possible in children to control the vein with just a clip. Once the vessels are taken, the kidney should appear dusky and, if not, the search for further vessels is undertaken. This can usually be performed by clearing the medial aspect of the kidney. The adrenal vessel are usually easily seen and preserved. Inferiorly, the ureter is identified and while it may be used as a handle to move the kidney, it is usually simply cut below the lower pole. The posterior and superior aspects of the kidney are then mobilized and the kidney is freed.

23.1.3.1.6. Completion

After complete removal of the kidney, we check the renal bed for bleeding. If this is dry, the kidney is removed through the 12-mm working laparoscope port. This can be done by passing a 0 silk suture down the camera port, tying it around the specimen, then extracting it as the camera and port are removed. This allows the kidney to be removed through the larger port.

After the specimen is removed, the port sites are closed by tying the preplaced fascial sutures and closing the skin with subcutaneous sutures and local anesthetic. No catheter is left in place and the patient is discharged the same day or the first postoperative day.

23.1.3.1.7. Outcomes

Outcomes have been satisfactory with no major complications and in our experience, the need for conversion was only when the anatomy was extremely complex in one case. In older patients, the recovery time is more rapid than open surgery, but this has not been examined rigorously. We have combined unilateral nephrectomy with contralateral ureteral antireflux surgery in four patients with a refluxing nonfunctioning kidney and reflux on the remaining kidney. This appears to provide an excellent means of dealing with two surgical problems using only four ports. We do, however, recommend stenting the solitary kidney.

23.1.3.2. Partial Nephrectomy

23.1.3.2.1. Setup

Partial nephrectomy is prepared and setup in the same manner as for simple nephrectomy. No catheters are placed in the ureters, but a bladder catheter is left in place for the procedure. Adequate preoperative imaging to define the anatomy and functionality of the renal units is essential.

23.1.3.2.2. Instrumentation

Instrumentation needed for the procedure includes: 5-mm hook cautery; 5-mm Maryland dissector; 5-mm needle driver; and 5-mm scissor.

23.1.3.2.3. Procedural Steps

The essential elements of the procedure are to mobilize the lower pole of the kidney, identify the ureters of the upper and lower poles, and then to trace the affected pole's ureter up to the hilum of the kidney. At this point it is necessary to identify the major renal vessels and identify the vessels to the pole to be removed. They are usually smaller, but may also be more aberrant. These vessels, once identified, are ligated with suture or clip, and divided (Figure 23.4). The ureter to the affected pole is then used to develop the plane between the two poles. As this place is identified, the separation of the two poles is performed using either electrocautery or harmonic scalpel. The renal parenchyma is usually thin and easily incised. Any bleeding should be handled with a suture ligature. Once the affected pole is removed, the edges are sewn together with a large mattress suture of absorbable suture with an inlay of fatty tissue.

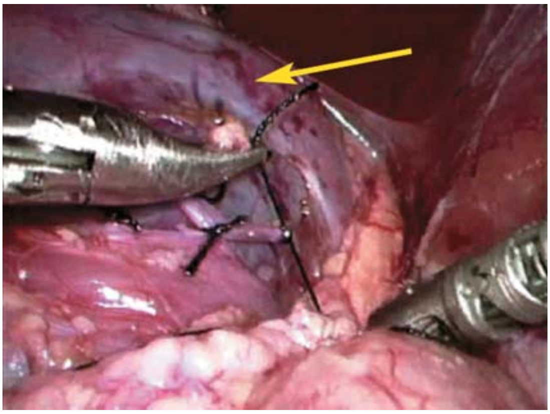

FIGURE 23.4. View of the hilum of the kidney with the artery to the upper pole which is to be removed indicated by the arrow, being ligated prior to dividing.

23.1.3.2.4. Completion

If there is any question of an injury to the remnant pole, it should be closed and the surgical field drained. Otherwise, there is usually no need for wound drainage. A bladder catheter is not left in place in most cases.

Patients are checked with renal ultrasound in four to six weeks to make sure the remnant pole is draining well and not injured. Occasionally a fluid collection is seen, and these are usually left alone and rarely, if ever, create a clinical problem.

23.1.3.2.5. Outcomes

There are few report of robotic-assisted partial nephrectomy in children, but anecdotal reports have been positive with no major complications and rare conversions.[8] Our experience has been very good, with upper and lower pole partial nephrectomy in 10 cases.

23.2. Other Procedures

A variety of other procedures have been explored using robotic assistance in pediatric patients, most in very limited numbers. They evolve from the experience generated performing the procedures listed above and reflect a slowly growing comfort with renal and pelvic reconstructive

Table 23.1. Procedures utilizing robotic assistance in pediatric patients.

Procedure	Comment
Re-operative pyeloplasty	Open and laparoscopic prior surgery
Pyelolithotomy	Large stone burden cystine stones
Appendicovesicostomy	Two primary; one re-operative (also reported by Pedrazzaet al.[9])
Müllerian duct excision	Including large seminal vesicle cysts
Adrenalectomy	One converted due to size and patient body habitus
Bladder neck sling	Male epispadias patient
Uretero–ureterostomy	Similar to pyeloplasty

and ablative surgery with the da Vinci® robotic system. Detailed descriptions are beyond this chapter, although the basic methods reflect standard access and exposure techniques combined with the performance of the procedure using standard steps.

Procedures performed are listed in Table 23.1. It is unclear if any or most of these procedures may be performed regularly using laparoscopic and robotic methods, but this experience emphasizes the flexibility of the system, which should not be seen as a one-trick pony.

23.3. Conclusion

Robotic assistance in pediatric urology has opened a door to the potential widespread use of laparoscopic techniques for reconstructive procedures in children of all ages. The benefits appear to be those of laparoscopy in terms of excellent exposure, minimal surgical trauma, and rapid recovery, without the extensive learning curve and limitations in dexterity that has limited application of laparoscopic methods to a few centers. As the instruments evolve in terms of size, cost, and efficiency, so will the procedures and the methods used today are likely to be very different in the upcoming years.

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24

Robotics and Infertility

Sejal Dharia Patel

Surgery in the field of reproduction has traditionally been taught utilizing tradition laparotomy incision. The advantages of the laparotomy approach include depth perception and tactile feedback from the resistance of tissue/organ dynamics. In addition, there is an ease of intra-abdominal suturing from the six degrees of freedom afforded from the human wrist. Although a laparotomy is advantageous for the surgeon compared to other surgical techniques, there are disadvantages for the patient, including a large abdominal incision, prolonged hospitalization, increased postoperative analgesic requirements, and increased morbidity.[1,2] This has led some surgeons to seek out minimally invasive approaches. The first laparoscopy was described by Ott from Petrograd, who inspected the abdominal cavity using a head mirror and an abdominal wall speculum in 1901, calling the procedure *ventroscopy*.[3] However, it was the first International Symposium of Gynecologic Endoscopy in 1964 that initiated interest in laparoscopic tubal sterilization,[4] gamete intrafallopian tubal transfer,[5] and other laparoscopic gynecologic procedures in the ensuing four decades.[6] Laparoscopy offers advantages to the patient: improved cosmesis, decreased blood loss, less postoperative analgesic requirements, shorter hospitalization time, and quicker recovery.[1,2] However, its usefulness is limited due to the steep learning curve for surgeons. Other obstacles include limited dexterity, counterintuitive motion, two-dimensional vision, and ergonomic difficulty. Tremor amplification can also occur from the use of long rigid instruments for prolonged periods of time in a fixed position.[7] In laparoscopic surgery, the fulcrum point created by the trocars limits the surgeon to four degrees of freedom, reducing dexterity.[8] In addition, because of the fulcrum at the trocars, the movements of the surgeon's hands results in movements in the opposite direction at the working end of the laparoscope, making movements counterintuitive.[7] The laparoscopic surgeon must also accommodate to a two-dimensional screen, which limits depth perception as compared to the three-dimensional vision afforded by open surgery.[7] Ergonomics is also impacted by traditional minimally invasive surgery.[8] In a survey by Society of American Gastrointestinal Endoscopic Surgeons, 8% to 12% reported pain or numbness in the arms, wrists, hands, or shoulders after performing laparoscopic surgery,[9] which has been confirmed by electromyographic data.[10] These limitations can be overcome if the surgical procedure is facile and efficient.

Simple reproductive procedures, such as ovarian cystectomy and cauterization of endometriosis, are examples of procedures that can be effectively performed through laparoscopy and have obtained popular acceptance since their first description in the 1970s.[6] It is the more complex, advanced laparoscopic cases that present a challenging learning curve, including microsurgical tubal reanastomosis.

Robotic technology, more specifically, telerobotic surgical systems, offers the opportunity to bridge this gap between laparotomy and laparoscopy by enabling minimally invasive surgery with three-dimensional vision, ergonomically optimal positioning, tremor filtration, and laparoscopic instruments with intra-abdominal articulation.[11]

24.1. Current Applications of Robotic Surgery in Reproductive Endocrinology and Infertility

Although reproductive endocrinologists were among the first to use laparoscopic surgical techniques, the role of robotic surgery in reproduction has developed after other surgical specialties.

In the subspecialty of reproductive endocrinology, a few procedures have been reported using robotic technology (Table 24.1).

24.1.1. Female

24.1.1.1. Tubal Reversals

One of the original procedures to gain popularity was the microsurgical tubal reversal. Using the Zeus® surgical system (Computer Motion), the first procedure performed was microsurgical uterine horn anastomoses in six female pigs in 1998.[12] This procedure capitalizes on the advantages of the robotic system by providing the fine motor movements required for intracorporeal suturing, three-dimensional vision, and motion scaling to assist in microsurgery. Falcone and colleagues[13] performed the first human clinical trial using the Zeus® robotic system in 1998 on 10 patients with previous tubal ligations who underwent a robotically assisted laparoscopic tubal reanastomosis. The setup included placement of the ports in the lower quadrants bilaterally for the robotic arms and one port was placed suprapubically for introduction of suture. To perform the reanastomosis, 6-0 polygalactin (Polyglactin 910, Ethicon, Inc., Piscataway, NJ) was used on the mesosalpinx and 8-0 used on the fallopian tube. The mean operative time to perform the anastomosis was 159 ± 33.8 min. Chromopertubation established patency in 17 of 19 tubes reanastomosed with a pregnancy rate of 50%. They then compared their robotic reanastomoses to traditional laparoscopic reanastomosis and found that operative times were significantly longer (two hours) with use of the Zeus® robotic system, but all other outcomes were comparable.[14] Degueldre and colleagues[15] then performed a feasibility study with the da Vinci® Surgical System (Intuituive Surgical Inc., Sunnyvale, CA) on eight patients. The mean operating time was 181.5 min and although follow-up was limited to four months, two of the eight patients achieved a pregnancy and five of eight patients demonstrated at least unilateral patency. Subsequently, Dharia and colleagues[16] performed a feasibility study in a fellowship training program using the da Vinci® Surgical System on 18 patients who desired reversal of tubal sterilization and compared these to 10 patients who underwent a traditional open microsurgical reanastomosis. Main outcome measures included pregnancy rates, tubal patency, postoperative analgesic requirements, time to recovery of independent activities of daily living and time to return to work.

Table 24.1. Robotic procedures in reproductive medicine.

Female reproductive surgery	Male reproductive surgery
Tubal reanastomosis	Vasovasotomy
Myomectomy	Vasoepididymostomy
Ovarian transposition	Varicocele ligation
Gonadectomy	

After induction of general anesthesia, the patient was placed in a modified dorsal lithotomy position in Trendelenburg, and mobilization of the uterus was provided with an intrauterine cannula. The da Vinci® surgical tower was positioned between the patient's lower extremities and port placement as described in Figure 24.1. Peritoneal access was obtained using a 12-mm trocar through the umbilicus. Two lateral 8-mm ports (Intuitive Surgical Inc.) were placed in the mid axillary line 2 cm below the umbilicus and separated by a minimum of 8 cm between port sites. At this point, a diagnostic laparoscopy was performed to assess the feasibility of the reanastomosis with lysis of adhesions if necessary. An accessory 10-mm port, placed on the left side between the umbilical and the lateral port was used for irrigation, placement, and removal of sutures.

Once the setup is completed, two microforceps are placed in each axillary port. The initial step is to prepare the distal tubal segment. This is done by stripping off its serosa using microscissors. With the serosa stripped off, the tip is resected to express the lumen with protrusion of endosalpinx. Attention is then turned proximally. The microforceps is switched out with cautery

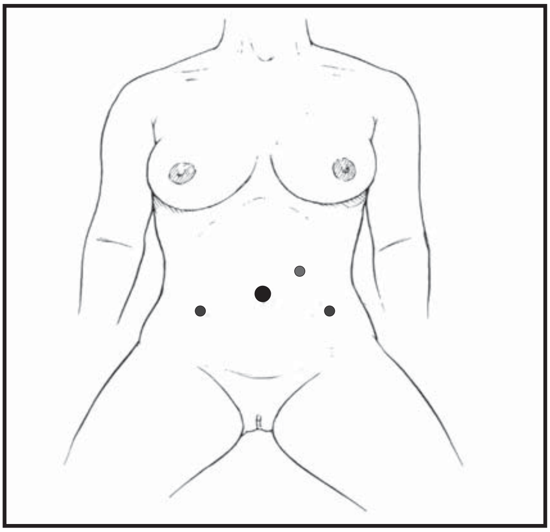

Figure 24.1. For robotic tubal reversals: Once peritoneal access is obtained, a 12-mm camera port (black) is placed at the umbilicus. Subsequently, two da Vinci® ports (blue) are placed in the midclavicular line, 1 to 2 cm below the level of umbilicus, lateral to the rectus muscle. An additional accessory port (red) on the left side of patient is used for irrigation, placement, and removal of sutures.

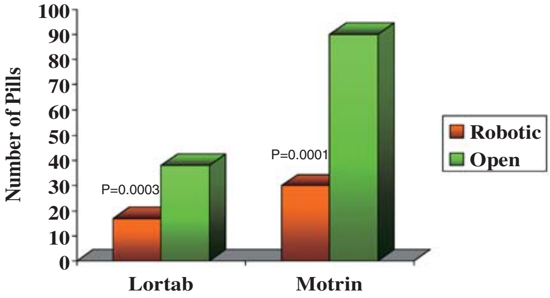

Figure 24.2. All patients who underwent a robotic tubal anastomosis were discharged home within four hours as compared to patients who underwent a open reversal, who on average were hospitalized for 36 hours.

and the proximal segment is dissected free from the mesosalpinx. The occluded segment is opened with laparoscopic endoshears placed in the axillary port. Proximally, chromopertubation demonstrated patency of the proximal tubal segment. The mesosalpinx was re-approximated with interrupted 6-0 delayed absorbable (vicryl) sutures in order to bring the mucosal edges in close proximity to prevent tension on the anastomosis.

The mucosal and muscular layers of the tubal segments are sutured with four interrupted 7-0 prolene sutures. The use of intra-abdominal articulation allows generous range of motion with a fine diameter suture. The serosa is closed separately with a running 7-0 prolene suture. Patency is determined by chromopertubation.

Our patients were similar in regards to demographics including age, body mass index, years from tubal ligation, and type of tubal ligation. Our operative times were significantly greater in the patients who underwent robotic-assisted surgery, however, hospitalization time (Figure 24.2), analgesic requirements (Figure 24.3), time to recovery, and time to return of independent activities of daily living were significantly shorter in the robotic group. Tubal patency rates for those not pregnancy were 100% and pregnancy rates were 62% in the robotic group and 50% in the patients who had a open procedure, comparable in both groups.[16] Although limited, a preliminary cost-effective analysis demonstrates comparable cost per delivery in patients who underwent a robotic tubal reanastomosis ($92,488.00) as compared to those underwent a traditional open reanastomosis ($92,205.90).[17]

24.1.1.2. Myomectomy

Uterine myomas are found in 33% of the population, however, only account for approximately 3% of infertility. This is most commonly found when

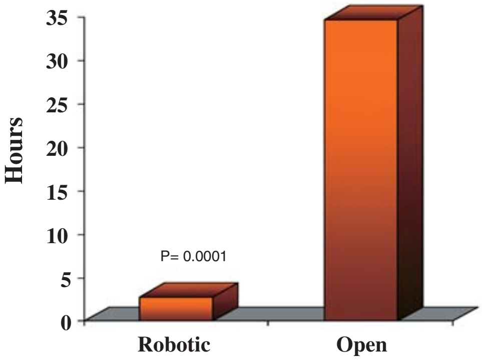

Figure 24.3. All patients were given fixed amounts of prescription narcotics and anti-inflammatory medication and tracked their medication usage. Patients who underwent a robotic tubal reversal used approximately one third of the medication allotted as compared to those who underwent a open procedure.

the myomas is local in the submucosal cavity or when the myoma is obstructing the tubal ostia. There are multiple therapeutic options, however, for those seeking to preserve fertility the most predominant form of therapy is a surgical myomectomy. Traditionally, myomectomies were performed through a laparotomy incision. Then popular support emerged for laparoscopic myomectomies to provide the advantages of a minimally invasive approach to patients. However, some of the earlier series reported an increased incidence of uterine rupture during pregnancy. This was attributed to the difficulty in laparoscopic suturing, which resulted in fewer sutures and a weaker closure.

Advincula and colleagues[18] reported their preliminary experience with the use of the robot for laparoscopic myomectomies (port placement; Figure 24.4). In this report of 35 patients, the mean weight of the leiomyoma was 223 ± 244 g [95% confidence interval (CI), 135–310], the mean number of leiomyomas was 1.6 (range, 1–5), and the mean diameter was 7.9 ± 3.5 cm (95% CI, 6.6–9.1). The mean blood loss was 169 ± 198 mL. The mean operative time was 230 ± 83 min (95% CI, 201–260). Five cases required between 350 and 400 min to complete the procedure. There was a trend toward decreased operative times with experience. There were three conversions to laparotomy.

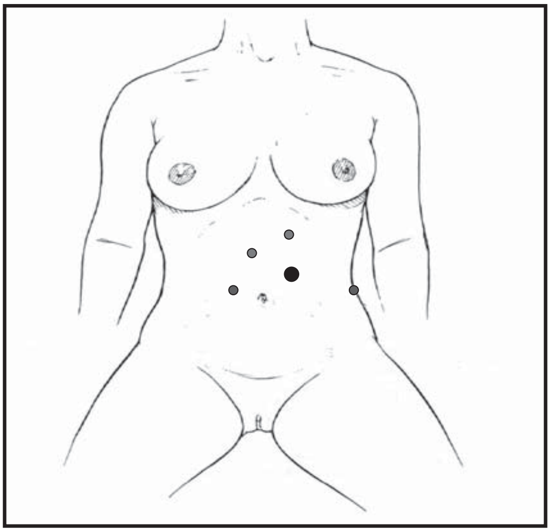

FIGURE 24.4. For robotic myomectomies: Once peritoneal access is obtained, a 12-mm camera port (black) is placed at the umbilicus. Subsequently, two da Vinci® ports (blue) are placed in the midclavicular line, 1 to 2 cm below the level of umbilicus, lateral to the rectus muscle. An additional accessory port (red) on the left side of patient is used for placement of the tenaculum and morcellation. An additional accessory port can be utilized if needed for placement, removal of sutures, and irrigation.

There are no published comparative clinical trials of robotic surgery with laparoscopic myomectomy or hysterectomy. However, when we compare these robotic results to published trials[19] without the robot there does not appear to be any advantage with these prototypes. It is possible that these robots may be more useful to the surgeon who is presently performing these procedures by laparotomy to perform them by laparoscopy rather than in the hands of the expert laparoscopic surgeon.

24.1.1.3. Others

There are case reports of the use of the robot with other less common procedures. In a case report, the da Vinci® Surgical System was used without complication to perform an ovarian transposition in a patient before she received radiotherapy for a stage 1B-1 cervical cancer.[20] Three interrupted 3-0 silk sutures were used to suture the transected utero-ovarian ligament to the psoas muscle.

The role of robotic surgery has also been investigated in the pediatric and fetal population. Gutt and colleagues[21] performed a bilateral gonadectomy in a 16-year-old pediatric patient with a gonadoblastoma. Using the da Vinci® Surgical System, the operative time was 95 min and no complications were reported.

24.1.2. Male

The role of robotics in male infertility has centered around vasectomy reversals and a reported case of a varicocele ligation. The first reported vasovasotomy utilizing a single-layer closure in a model system (rat) was presented in 2001 by Schoor, Ross, and Niederberger.[22] Subsequently, two additional authors evaluated the feasibility and the efficacy of robotic microsurgical vasovasotomy and vasoepididymostomy in a rat model utilizing either a single layer versus a multilayer closure.[23,24] In a prospective, randomized study using the male Wistar rat, Schiff and coworkers utilized 24 male rats and randomized them to a microsurgical multilayer vasovasotomy or a longitudinal vasoepidymostomy as compared to the robotic approach. Their finding included no complications in either group. The robotic approach for vasovasotomy was significantly faster than the conventional technique (68.5 vs. 102.5 min; $p = 0.002$). In terms of outcomes, patency rates were equal and sperm granulomas were found in a higher percentage of those patients who underwent a traditional vasovasotomy. There was no difference in the robotic versus open vasoepididymostomy outcome parameters.[24] This equivalence in data was followed by a comparison between robotic and traditional microsurgical vasovasotomy in ex vivo human vas specimens. This study utilized 10 samples and a modified single-layer technique. The mean operative time and adverse haptic events were longer and larger, there was a complete elimination of tremor. The patency rates were also comparable. Their experience with robotics to account for the learning curve association with adverse haptic events was not extensive.[25]

One reported technique (in a rat model) involves positioning the da Vinci® surgical cart at a 10° angle and to the rabbits abdominal wall. Motion scaling was set a 5:1. The anastomosis was performed using four, 10-0 nylon double-armed fishhook needles for the mucosa, which were placed, and ligated down using the surgical system and black diamond microforceps. At least six additional sutures were placed to support the anastomosis at the muscularis layer. The sutures were cut using the Pott scissors. After the anastomosis was completed on one side, the testicle was returned to the scrotum on that side and the contralateral side was prepared and anastomosed in a similar fashion.

To our understanding, there is no published data relating to the clinical use of microsurgical vasovasotomy in humans, although both animal and ex vivo data appear promising.

24.1.2.1. Others

Cadiere and colleagues reported on one case of robotic-assisted varicocele ligation using the da Vinci® Surgical System, stating its feasibility and ease with the ability to eliminate tremor, possess three-dimensional vision, and the ability to articulate in anyone of second degrees of freedom.[26]

24.2. Conclusion

The role of robotics in gynecology appears to enable the surgeon to provide a minimally invasive approach to the patient, whilst performing the procedure according to the standard, the traditional open approach. With U.S. Food and Drug Administration (FDA) approval relatively recently applied to gynecology, robotics in gynecology will continue to evolve and the surgical outcomes and cost effectiveness will determine its eventual role in obstetrics and gynecology.

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25

Robotic Urogynecologic Surgery

Daniel S. Elliott, Amy Krambeck, and George K. Chow

To date, there has been limited research and reporting in obstetric, gynecological, and female urology literature concerning the use of robotics. Robotics has been utilized only for the treatment of two benign gynecologic conditions: benign hysterectomy[1] and sacrocolpopexy, which is a treatment for posthysterectomy vaginal vault prolapse (VVP).[2,3] However, laparoscopy has been utilized extensively in gynecologic surgeries and has demonstrated itself to be invaluable with procedures such as total and supracervical hysterectomies and for the evaluation and treatment of endometriosis.[4] More recently, laparoscopy has been reported for staging purposes of gynecologic malignancies, for the treatment of early stage endometrial cancer, and the treatment of ectopic pregnancies.[5–7]

To demonstrate robotics potential benefit for other areas of gynecology, this chapter will focus on the emerging benefit discovered for the treatment of VVP.

It has been estimated that one in nine women will undergo a hysterectomy in their lifetime, and up to 10% of these women will need surgical repair for treatment of a major, symptomatic vaginal prolapse.[8] The search for the type of repair that is the most effective, safe, and durable for the treatment of VVP is an ongoing process, as evidenced by the multiple surgical approaches to this problem. Clearly, no one surgical approach is ideal for every patient. However, as the known risk factors for prolapse, such as age, obesity, and hysterectomy, continue to increase in the United States, so does the need for continuing the search for better means to repair VVP.[9–11]

Currently, the transabdominal sacrocolpopexy has been shown, on multiple studies, to have one of the highest long-term success rates for durable repair of severe vault prolapse (93%–100%).[12–20] In addition to a high success rate and durable results, other advantages of the sacrocolpopexy approach using synthetic material to repair vault prolapse can be summarized as follows:

1. Support of the vaginal vault to the anterior surface of the sacrum preserves (or restores) the normal axis of the vagina.
2. Maximal vaginal depth can be preserved, which is especially important in patients who desire continued sexual activity and in patients with an already foreshortened vagina from previous surgery.
3. Use of synthetic suspensory material can provide a source of strength in patients where the native tissue with prolapse is weak.[12]

Potential candidates for the open procedure tend to be younger patient and those who are more active and are more likely to be leading an active lifestyle. Other important indications are concurrent medical conditions, such as chronic cough, chronic obstructive pulmonary disease (COPD), and asthma. These conditions place chronic and repeated increased intraabdominal pressure on the repair. Unfortunately, due to the morbidity of the open transabdominal procedure, many patients are unable to tolerate the surgery. Therefore, many of these patients are treated via a transvaginal approach.

The goals of every surgical repair of VVP include restoration of proper anatomy, maintenance of sexual function, and durability. Surgical approaches to correct the prolapse include either a vaginal or an abdominal approach or a combination of both. The main advantage to vaginal approach has historically been decreased morbidity, including shorter hospitalization and convalescence.[21,22] Unfortunately, long-term success rates with transvaginal repairs are consistently lower compared to the abdominal approach, such as sacrocolpopexy.[23]

In an effort to balance the benefit of the open sacrocolpopexy (durable repair) with the advantage of a vaginal repair (reduced morbidity), many attempts have been made with treating the vault prolapse via laparoscopic sacrocolpopexy.[24,25] Unfortunately, technical difficulties in actually accomplishing the procedure and the potentially significant increase in operative time has greatly limited its widespread use. To address these specific limitations of laparoscopic repairs, we feel that recent advances in robotic surgery may be an answer.

25.1. Robotic-Assisted Laparoscopic Sacrocolpopexy Surgical Technique

The patient is placed in the dorsal lithotomy position on the operating table. After general anesthesia is administered, a nasogastric tube is placed and both arms are tucked beside the torso. The patient is prepped from the nipples to proximal thigh, including the vagina.

After abdominal insufflation using a Varus needle, we place a periumbilical camera port under direct vision to avoid visceral or vascular injury. Two standard laparoscopic ports are next introduced under direct vision: one 10-mm port right subcostal lateral to the rectus and one 5-mm port one hand's breadth inferior laterally (Figure 25.1). These ports are used for retraction during the procedure. Next, two 8-mm robotic ports are placed lateral to the rectus two fingerbreadths superior to the ileac crest.

At this point, using standard laparoscopy, a retracting suture is placed through the sigmoid tenia to eventually help in exposing the sacral promontory. The next step is dissection of the bladder from the anterior vaginal wall using forceps and scissors with cautery. A customized handheld vaginal retractor manufactured at the Mayo Clinic (Figure 25.2) is used to facilitate the dissection, which should be a relatively bloodless plane. Posteriorly, the peritoneal reflection is then incised to mobilize the vagina. Both of these dissections should be carried out as distal (toward the introitus) as possible to maximize the support given by the Y-graft. After adequate vaginal mobilization, the sacral dissection with careful attention to avoid sacral venous complexes is

Figure 25.1. Port placement for robotic-assisted laparoscopic sacrocolpopexy.

Figure 25.2. Handheld vaginal retractor.

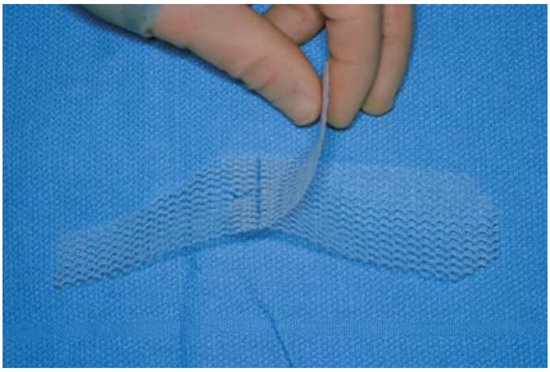

Figure 25.3. Polypropylene sacrocolpopexy Y-graft.

accomplished. Once the shiny periosteum is exposed, the polypropylene Y-graft (IntePro^{TM}, American Medical Systems, Minnetonka, MN; Figure 25.3) is brought into the field through the 10-mm port. To date, in our experience, the aforementioned steps can be accomplished within 30 to 40 min.

The robot is now docked with the base positioned at the foot of the bed. The main reason to utilize the robot at this point in time is to facilitate and greatly reduce the operative time needed for suturing of the graft to the vagina and the sacrum. The Y-shaped graft is inserted via a port. The graft is then robotically sutured using 1.0 GoreTex®. The 30° lens and vaginal retractor maximize exposure for placement of the sutures. We have found that placing the posterior sutures first, because they are more difficult, followed by suturing the anterior portion of the Y-graft, reduces the difficulty of the process. The tail end of the graft is then sutured to the sacral promontory using three to four interrupted sutures with careful attention to avoid any undo tension to the vagina. We also perform a standard Halban's culdoplasty with plication of the uterosacral ligaments to further aid in the prevention of recurrent vaginal prolapse. The posterior peritoneum is then closed to completely retroperitonealize the graft.

25.2. Results

At our institution, we have performed robotic-assisted laparoscopic sacrocolpopexy on 31 patients for the treatment of high-grade symptomatic VVP over that past 24 months. Mean age is 66 (range, 47–82) years. Ten patients of the 25 patients (40%) underwent concurrent anti-incontinence procedure at the time of the prolapse repair to treat concurrent stress urinary incontinence. Mean total operative time was 3.2 (range, 2.5–4.75) h. Initially, the skin-to-skin time was 4.75 h. However, with experience and utilizing multiple timesaving steps, we are now routinely completing a case in under 2.5 h.

One patient had to be converted to an open procedure secondary to unfavorable anatomy. All but one patient were discharged from the hospital after an overnight stay; one patient left on postoperative day 2. All patients were dismissed on oral pain medication. Ten of the patients have reported they only required nonsteroidal anti-inflammatory medication for control of their pain. One patient had persistent vaginal bleeding for two days postoperatively, a complication related to the antiincontinence portion of the case, not the prolapse repair. Her hemoglobin remained stable with no further sequelae.

25.3. Complications

Complications were limited to mild port site infections in two patients, which resolved with oral antibiotic therapy. One patient developed recurrent grade three rectocele, but had no evidence of cystocele or enterocele. One patient developed an small erosion of the synthetic cuff into the vagina six months following the procedure. This was easily managed with an outpatient, transvaginal excision. Significant incontinence (>1 pad/day) was present in two patients. Twenty-nine out of 30 patients reported being satisfied with the outcome of their surgery and would recommend it to a friend. The one patient who did not recommend the procedure was the solitary patient converted to an open procedure.

25.4. Limitations of Robotic-Assisted Sacrocolpopexy

One of the obvious limitations with this procedure is the learning curve associated with laparoscopy itself. Clearly, the technical aspect of laparoscopy requires advanced training; however, with the addition of robotics, the technical difficulty of the procedure is actually reduced. Individuals with basic laparoscopy skills usually are able to master the procedure when it is combined with robotics. However, the robotics system is expensive.

25.5. Conclusion

We feel, and the data supports, that transabdominal sacrocolpopexy is the most durable and effective treatment of posthysterectomy VVP. However, not every patient is a candidate for this procedure due to age, concurrent medical conditions, or concerns regarding postoperative recovery time. We also feel that the advantage of a robotic-assisted laparoscopic sacrocolpopexy is that it accomplishes the identical repair as that of the open transabdominal technique. The morbidity associated with the open procedure is greatly reduced and the hospital stay has been reduced from two to five days with the open procedure, down to one day with the laparoscopic repair.[26,27] Also, based upon early, short-term results, it appears that the durability of the repair will be the same as with the open procedure. Potentially, many more women will be able to be offered the strongest repair for prolapse while still keeping morbidity to a minimum. As long-term results become available, we will better be able to determine the durability of this repair.

Relative contraindications would be the same for most laparoscopic procedures, including patients with prior abdominal surgeries and those with morbid obesity. Clearly, longer follow-up is needed; however, the robotic-assisted laparoscopic sacrocolpopexy described in this report may be an ideal approach to the surgery repair of VVP.

25.6. The Future of Robotics in Urogynecology

Though the robotics experience is early, the potential for robotics in this surgical specialty is significant. Clearly, there are limitations to robotics; however, because many gynecologic surgeons feel comfortable with the use of laparoscopy, the potential to transfer those skills to robotics is clearly present and the benefit to patients potentially dramatic.

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26
The Future of Telerobotic Surgery

Garth H. Ballantyne

The confluence of minimally invasive surgery, integrated operating rooms, and telerobotic surgery promises substantial advances for all types of surgery in the 21st century. Laparoscopic approaches to minimally invasive surgery have won dramatic gains for patients in terms of short-term outcomes. Integrated laparoscopic operating rooms insert teleconferencing capabilities into surgical suites and offer easy access to telementoring for inexperienced surgeons during the steep learning curves of many advanced minimally invasive surgical procedures. The rapid evolution of robot-assisted surgery into telerobotic surgery provides technologic solutions to many of the inherent limitations of laparoscopic surgery. Moreover, the surgeon's console of telerobotic surgical systems provides a platform for integration in novel formats of the varied forms of digital information currently generated for surgical patients. The melding together of minimally invasive techniques, telerobotic surgical systems, and integrated patient-specific digital information will catapult surgery of the 21st century into patient-specific surgical simulation, augmented reality surgery, and novel approaches to surgical training.

The purpose of this chapter is to highlight the patient-specific advantages accrued by minimally invasive approaches to abdominal operations. We will review preliminary experience with telementoring and explore the potential role of telepresence surgery in delivering surgical care to remote areas, in space, and on the battlefield. We will then detail the initial forays into patient-specific surgical simulation and augmented reality surgery. Finally, we will suggest the potential use of virtual reality systems in surgical training.

26.1. Telementoring

The advent of laparoscopic surgery forced a reappraisal of mechanisms for the introduction of new surgical procedures into surgical practice. Various surgical societies and state governments have suggested procedures to follow.[1] These typically include (1) board certification, (2) completion of a didactic course focusing on the particular procedure, (3) observation of an expert surgeon performing the procedure, (4) performance of the procedure using a cadaver or live animal model, (5) supervision of the novice surgeon's initial clinical experience by a preceptor for 5 to 10 operations, and (6) observation by a proctor during the subsequent 5 to 10 operations. This process can prove expensive when qualified preceptors or proctors are not available in the novice surgeon's home institutions. Integrated operating rooms offer an efficient and economical solution.

Many integrated operating rooms incorporate teleconferencing systems.[2] Laparoscopic operations offer an ideal arena for telementoring because both the surgeon and preceptor observe identical video images. In 1997, Rosser and associates first demonstrated the feasibility of teleproctoring, or telementoring, surgeons.[3] An expert surgeon supervised inexperienced surgeons performing laparoscopic colectomy and laparoscopic Nissen fundoplications first from across campus and then from a location five miles away. Similarly, in 1998, Kavoussi's group succeeded in telementoring 27 operations between the Johns Hopkins Bayview Medical Center and the Johns Hopkins Hospital, which are separated by 3.5 miles.[4] Based on this experience, the same group first accomplished international telementoring between the John Hopkins Hospital and hospitals in Innsbruck, Austria, and Bangkok, Thailand.[5] In 1999, surgeons in Maryland and California telementored surgeons at sea on the aircraft carrier U.S.S. Abraham Lincoln while performing five laparoscopic hernia repairs.[6] In 2000, Byrne and Mughal telementored surgical trainees in performing 34 laparoscopic cholecystectomies.[7] Only one operation was converted to an open operation. Between July 2002 and May 2003, experienced laparoscopic surgeons in Turin, Italy, telementored inexperienced surgeons 430 km away in Modena, Italy, during their initial experience with eight laparoscopic adrenalectomies.[8] All operations were successfully completed. In Munich, Germany, surgeons used a novel system incorporating the hospital local area network (LAN), an overhead video camera, and a robotic system controlling the laparoscopic video camera for teleproctoring 237 operations.[9] The proctor also used a telestator to annotate instructions on the video monitor. They found that the bandwidth in the hospital's LAN was adequate for both transmissions of the video and audio signals. These studies indicate that surgeons can successfully preceptor other surgeons from across campus or even between different continents. This significantly increases the pool of potential preceptors and significantly decreases the time investment required by the preceptor.

Recently, surgeons have used an even more flexible and inexpensive Internet system for telementoring. Surgeons control a mobile teleconferencing robot, RP-6™ (Intouch Health, Santa Barbara, CA), through a wideband encrypted virtual personal network (VPN) Internet connection.[10] The surgeon controls the movements of the robot with a computer gaming joystick attached to his desktop or laptop computer. Both the RP-6™ robot and the control station telecast both video and audio signals. The surgeon's face is projected on the flat screen that serves as the robot's head (Figure 26.1). The surgeon observes the patient's video image on the control station's monitor and talks with them through the audio signal transmitted by the robot over the wideband connection. The high-resolution camera zooms in when close inspection of wounds or the surgeon are required. In many hospitals, the surgeon can also access the patient's electronic medical record (EMR) via the same VPN. The great advantage of RP-6™ over standard teleconferencing is flexibility. The surgeon can visit his patient from anywhere in the world where a wideband Internet connection is available.

Patients welcome virtual visits by their surgeon. In 2004, Kavoussi's group at Johns Hopkins tested the impact of telerounding on patient satisfaction.[11] A total of 85 patients were divided into two groups. Attending surgeons rounded on one group with RP-6™ and while personally visiting the second. The telerounding patients reported significantly higher satisfactions scores. Interestingly, the telerounding patients thought that their attending surgeon showed greater availability than the patients who were actually visited by the surgeons.

Remote mobile teleconferencing via the Internet may also facilitate telementoring. In a preliminary study at Emory University School of Medicine, Smith and Skandalakis used the RP-6™ teleconferencing robot to proctor medical students during gross anatomy laboratories from a remote site.[12] Medical students and surgeons filled out questionnaires at the end of each cadaver session. All medical students judged the teleproctoring as a positive experience and often forgot that the surgeon was not actually present. This study suggests that surgeons may be able to telementor other surgeons in the operating room with the mobile teleconferencing robots. Using the Internet greatly simplifies access and may make telementoring more readily available. Mobile teleconferencing robots also offer other new possibilities. At Hackensack University Medical Center, we have used the RP-6™ robot for intraoperative consultations with other surgeons during difficult procedures.

Figure 26.1. RP-6™ is a five-foot five-inch tall, Internet-based mobile teleconferencing robot. This photograph shows Dr. Ballantyne, who is connecting from a remote site via a wideband Internet connection, giving a lecture at the MIRA (Minimally Invasive Robotics Association) Congress in New Orleans in 2004. RP-6™ also offers new opportunities for teleproctoring and telementoring in the operating room.

26.2. Telepresence Surgery

During telepresence surgery, the surgeon uses a control station at one location to perform an operation using a virtual operative field and robotic instruments on a patient at a remote location.[13] In 1991, Green and colleagues first demonstrated the feasibility of telesurgical procedures in which the surgeon is remotely separated from the patient.[14] The concept guiding the development of telerobotic surgical systems envisioned a military surgeon sitting at a control station situated on an aircraft carrier or Mobile Army Surgical Hospital (MASH) unit operating on a wounded soldier in a robotic ambulance positioned on the battlefield.[15–18] In 1998, Bowersox and colleagues performed trauma surgery on live animal models with a prototype of a telerobotic surgery system. Surgeons used a control station at a remote site to close gastrotomies and enterotomies, to excise gallbladders, and to control hemorrhage from liver lacerations in pigs.[19] These surgeons offered this important observation: "The premise of removing a surgeon's hands from the patient and replacing them with an electromechanical linkage challenges a fundamental tenant of surgery . . . that it is feasible to perform surgery through an electronic interface without directly seeing or touching the patient." Based on these seminal studies, surgeons proceeded to perform telepresence operations on patients.

Both the Zeus® (Computer Motion, Santa Barbara, CA) and da Vinci® telerobotic surgical systems (Intuitive Surgical Inc., Sunnyvale, CA) were initially designed to permit remote telepresence surgery.[20,21] In 2001, Marescaux and colleagues accomplished the first intercontinental, telepresence operation on a patient.[22–24] Marescaux sat at a control station in New York City and used the robotic arms of a Zeus® system to remove a patient's gallbladder in Strasbourg, France. A distance of 3800 miles separated Marescaux from his patient. A trans-Atlantic fiber optic cable connected the control station to the robotic arms. Marescaux completed the operation without difficulty. The patient recovered without complication.

Telepresence surgery offers expert surgical care for remote areas. At McMaster University in Hamilton, Ontario, Canada, Anvari has implemented a telepresence surgical and telementoring program. A Zeus® control station in his office is linked by a commercially available IP/VPN network with Quality of Service to two community hospitals more than 400 km north of Hamilton. Initially, Anvari successfully performed 22 telepresence operations. These included telerobotic colon resections, telerobotic Nissen fundoplications, and telerobotic inguinal hernia repairs.[25] More recently, Anvari has used this telepresence surgical system for telementoring.[26,27] Inexperienced surgeons performed 10 laparoscopic bowel operations, 5 laparoscopic Nissen fundoplications, 2 laparoscopic splenectomies, 1 laparoscopic reversal of a Hartmann's procedure, and 1 laparoscopic ventral hernia repair. Two operations (11%) were converted to open operations. These studies suggest that telepresence surgery can be accomplished safely and that this technology may offer novel solutions to surgical manpower issues facing all societies in the 21st century.

26.3. The Operating Room as a Digital Information Platform: Surgery in Information Space

During the late 20th century, surgeons began a paradigm shift with the introduction of digital video imaging systems for laparoscopic surgery.[28,29] Use of digital signals stimulated the construction of integrated operating rooms: this represented the first phase of this paradigm shift.[9,30] Digitally integrated operating rooms facilitated the flow of digital information of various types into the operating room. Video monitors visually displayed patient-specific EMR. Nonetheless, the inherent two-dimensional nature of the monitors, available bandwidth, and computer chip processing rates severely constrained presentation of available data.[31] The insertion of telerobotic surgical systems into integrated operating rooms ignited the second phase (Figure 26.2).

Supercomputers drive telerobotic surgical systems such as da Vinci®. These systems contain the processing power to radically transform digital information into patient-specific virtual models that permit entirely novel approaches to surgery. Satava emphasizes that a surgical telerobot "is not a machine; rather, it is an information system with 'arms.'"[32] When connected through an integrated operating room to the hospital Intranet, the robot's computer gains access to patient-specific EMRs. It can take the digital information from the computerized tomography (CT) scan, magnetic resonance imaging (MRI) scan, ultrasound, and other diagnostic modalities, incorporating them into a patient-specific, three-dimensional virtual modal. This opens a portal permitting surgery in information space.[33] Using the surgeon's control station, surgical simulation, augmented reality surgery, and virtual reality surgical training becomes feasible.

26.4. Surgical Simulation

Surgeons view three-dimensional virtual video images of the surgical field at the surgeon's control station of the da Vinci® telerobotic surgical system. Additional imaging data can augment this virtual patient with images beyond the visual spectrum. Superimposition of patient specific, three-dimensional CT scan or MRI images onto the virtual video image generates an augmented reality environment.[34] The surgeon can then perform simulated cybersurgery.[35] Surgeons at the IRCAD-EITS in Strasbourg, France, developed a computer program that constructs a three-dimensional reconstruction of the patient and color codes important anatomical details.[36,37] This highlights, for example, malignant lesions

Figure 26.2. The computer console of the da Vinci® Surgical System radically extends the capability of the digitally integrated operating room. The console's computer can integrate the digital data from imaging systems such as CT and MRI scans into the three-dimensional virtual operative field. This enhanced environment creates augmented reality surgery that improves surgical planning, precision, and decision making.

and vital structures such as the common bile duct, hepatic arteries, and hepatic veins in the liver. The surgeon can use this augmented reality virtual model of his specific patient to plan the surgical approach to resection and, indeed, then perform surgical simulations.[38] Alternative strategies can be tested and then judged by blood loss, length of surgery, or extent of resection as to the best technique for this individual patient. Once satisfied with his preparation, the surgeon can then undertake an augmented reality operation.

26.5. Augmented Reality Surgery

Integrated images combining video, CT scan, ultrasound, and MRI data produce an augmented reality virtual model of a specific patient.[34,39] The surgeon views this enhanced virtual image of the patient at the surgeon's control station. Accurate registration of the different image sources represents the greatest challenge for this type of data integration at the present time. Once the pneumoperitoneum is insufflated, the trocars inserted, and the robotic arms attached, the surgeon's initial view shows not only the standard three-dimensional surface anatomy captured by the stereoscopic video telescope, but also the computer–color-coded structural anatomy.

During a cholecystectomy, for example, the surgeon might see the common bile duct and other biliary ducts coded as a green, the hepatic veins as blue, and the hepatic arteries as red. The surgeon sees all of these structures before dissection commences. Moreover, the computer understands the steps of the operation and enforces protection of vital structures. The computer will not permit the surgeon to cut the common bile duct. The computer will not permit the surgeon to activate electrocautery near the common bile duct within the thermal injury zone of the electrocautery setting being used.

In 2004, Marescauz and colleagues at the IRCAD-EITS reported the first augmented reality operation.[40] They accomplished the resection of an adrenal tumor with a Zeus® telerobotic surgical system. The surgeon observed color-coded anatomical structures from the preoperative CT scan superimposed on the three-dimensional video image. Augmented reality surgery promises to combine the precision of robotic instruments, the anatomical details available beyond the visible spectrum, and the judgment of the experienced surgeon.

26.6. Preoperative and Intraoperative Teleconsulting for Oncologic Surgery

Integrated operating rooms introduced connectivity to surgery. Most hospital Intranets are connected to the Internet. Surgeons at the IRCAD-EITS in Strasbourg, France, have developed software to facilitate simultaneous viewing of patient-specific, augmented reality representations of malignancies.[41] This permits surgeons at remotely separated sites to participate in preoperative surgical planning. Current technology also permits direct Internet-based communication between telerobotic surgical control stations. Given adequate bandwidth, two surgeons at remotely separated control stations could view the same patient-specific augmented reality representation of a malignancy and then engage in cooperative attempts at surgical simulations. The same mechanism also permits intraoperative consultations, surgical assistance, and telementoring by remote surgeons.

26.7. Surgical Simulation for Surgical Training

More than a decade ago, surgeons first augured that virtual reality systems would play an important role in surgical training for laparoscopic surgery.[42,43] Evolution of processing power and imaging capabilities rapidly improved the surgical simulations.[44,45] In 1999, Boston Dynamics introduced a surgical simulator for training and assessing laparoscopic suturing techniques. The system provided three-dimensional imaging, surgical instruments with force feedback, and metrics for assessing the surgeon's performance.[46,47] The metrics were able to distinguish the performance of medical students and skilled surgeons, and also documented the progression in skill at the tasks demonstrated by both groups. Also in 1999, surgeons at the Manchester Royal Infirmary in Manchester, United Kingdom, used another virtual reality laparoscopy simulator, MIST VR^{TM} (Virtual Presence Medical, London, UK), to evaluate 11 surgeons, 18 medical students, and 7 nonmedical personnel performing six laparoscopic tasks.[48] Scores reflected surgical experience suggesting that the six tasks were clinically relevant. A wide range of surgical simulators have been developed for various surgical specialties.[49,50]

Several groups have introduced surgical simulators for transurethral resection of the prostate (TURP). In 2002, Porter and colleagues at the University of Washington in Seattle, Washington, developed an image-based simulator to represent bleeding during TURPs.[51] In 2004, this group reported face, content, and construct validity for version 1.0 of the University of Washington virtual reality TURP trainer.[52] Surgeons judged the trainer slightly to moderately acceptable. Future predictive validity studies will test the translation of skills acquired on the trainer to clinical performance of TURP. In 2005, Kallstrom and colleagues in Linkoping, Sweden, reported a basic construct validity test for a virtual reality, real-time, surgical simulator for TURP.[53] The system projects a virtual view of the prostatic lumen and resectoscope tip. The surgical instruments provide force feedback. The virtual model simulates bleeding, irrigation, and pressure gradients. The construct validity testing of seven inexperienced urologists confirmed improved scoring with repetition. Virtual training systems are also available for ureterorenoscopy.

Groups from two universities have studied the role of surgical simulation for ureterorenoscopy. Urologists at the University of Texas Southwestern Medical Center in Dallas, Texas, have published a series of studies validating a virtual reality simulator. In 2004, Johnson and colleagues compared computer-based nonlinear causal resource analysis (NCRA) with expert-rated urologists in the scoring of performance of simulated ureteroscopic skills.[54] NCRA scores approximated those of the expert urologists. In a second validation study, inexperienced medical students improved their time to perform ureteroscopic skills by 50% and achieved scores similar to urology residents at the end of their first year.[55]

In a third study comparing virtual reality training to cadaveric models, performance improvement on both models was similar for medical students but not urology residents.[56] The authors concluded that the current iteration of virtual reality simulator might shorten the learning curve for trainees early in their programs but not for more experienced residents. Urologists in Mannheim, Germany, also studied the impact of surgical simulators on the performance of trainees at various levels.[57] Surgical residents with no experience in ureterorenoscopy improved their skills and achieved better scores with their first four clinical cases. These studies suggest that surgical simulators may play an important role for training residents during their initial learning curve before they attempt their initial clinical cases.

26.8. Surgical Simulators and Surgical Skills Competency

Various ethical concerns have generated interest in surgical training outside of the operating room prior to a surgical residents's initial clinical experience.[58] Virtual reality simulation offers an alternative training paradigm in which surgical residents acquire skills outside the operating room prior to their initial clinical performance of laparoscopic operations.[59] Surgeons in Eindhoven, The Netherlands, studied the impact of virtual reality surgical simulation on the performance of laparoscopic cholecystectomy by new surgical trainees.[60] The residents who underwent virtual reality training showed better surgical technique during their initial four laparoscopic cholecystectomies compared to trainees who had not used the surgical simulator. Darzi's group at the Imperial College in London, United Kingdom, has developed a competency-based virtual reality training curriculum.[61] Trainees practice 12 abstract laparoscopic tasks using the MIST VR™ virtual reality surgical simulator that teaches graduated levels of laparoscopic psychomotor skills. Although trainees master the graduated skills at different rates, once they achieve the preset criteria they are prepared to assist in and to perform clinical laparoscopic operations. These studies suggest that trainees should traverse the early part of their learning curve by practicing on virtual reality surgical simulators rather than at the expense of our patients.[62]

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62. Aggarwal R, Darzi A. Training in laparoscopy — which model to use? Indian J Gastroenterol 2005; 24:95–96.

Appendix A

Prostate Images

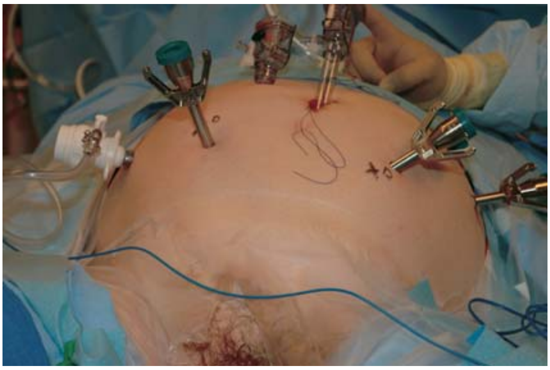

Figure A.1. Trocar placement.

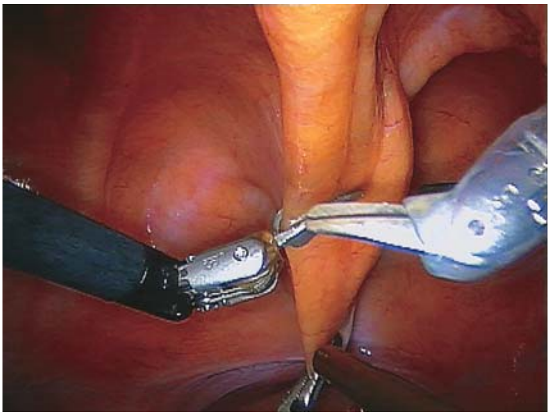

Figure A.2. Initial transperitoneal view.

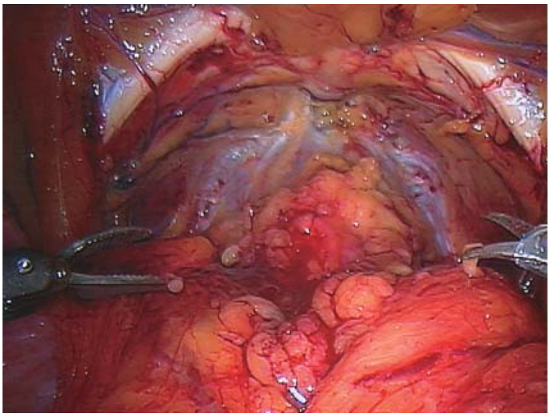

Figure A.3. View of the retropubic space after incision of the peritoneum.

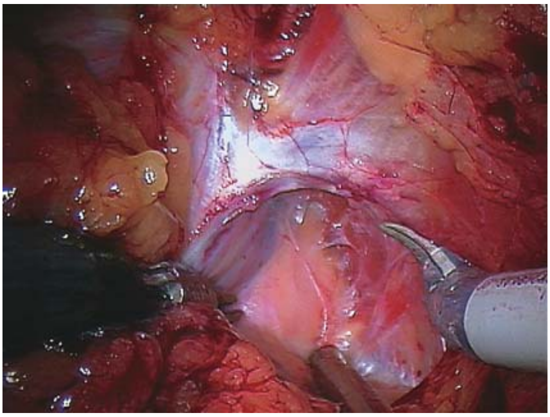

Figure A.4. Opening the endopelvic fascia at the base of the prostate.

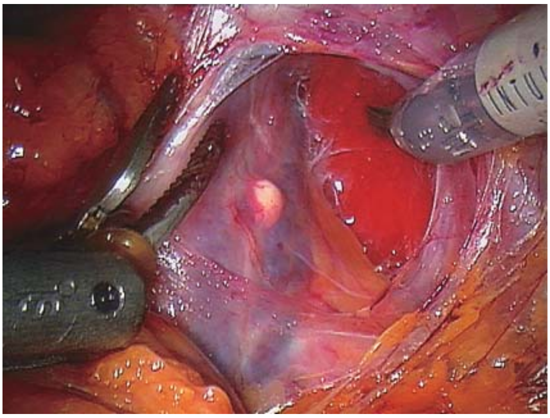

Figure A.5. Release of the levator muscle fibers.

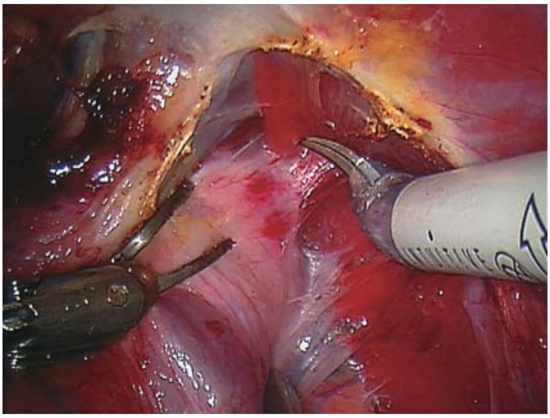

Figure A.6. Identification of the notch between the dorsal vein and urethra.

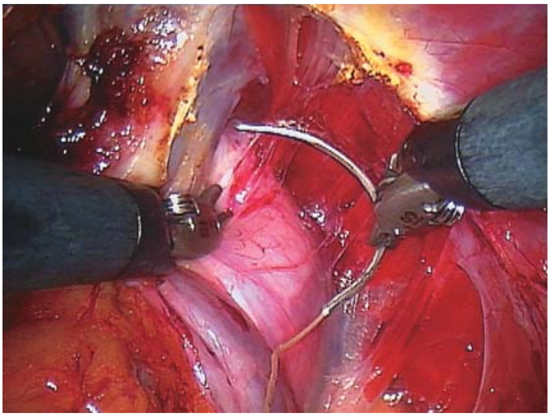

Figure A.7. Placement of the dorsal venous complex (DVC) suture.

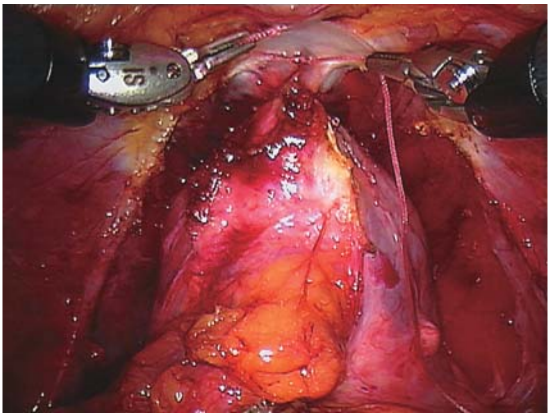

Figure A.8. Tying the DVC suture.

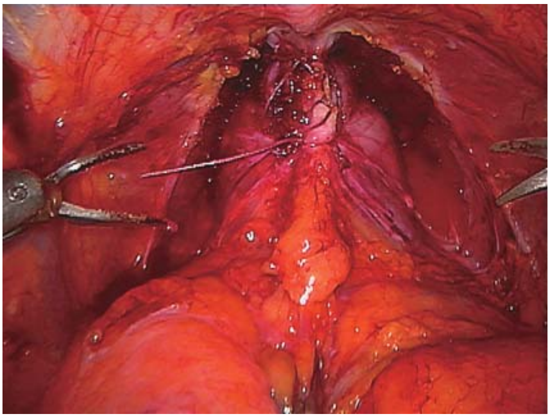

Figure A.9. Identification of the bladder neck.

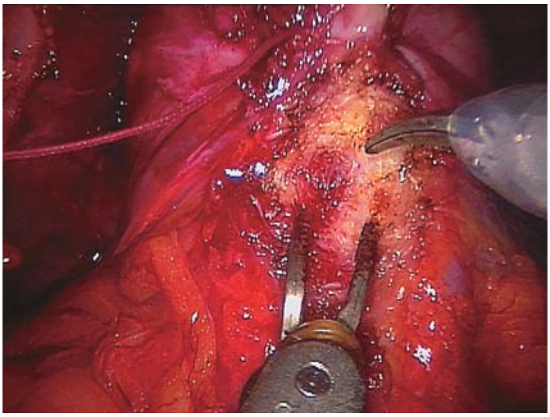

Figure A.10. Beginning the bladder neck dissection.

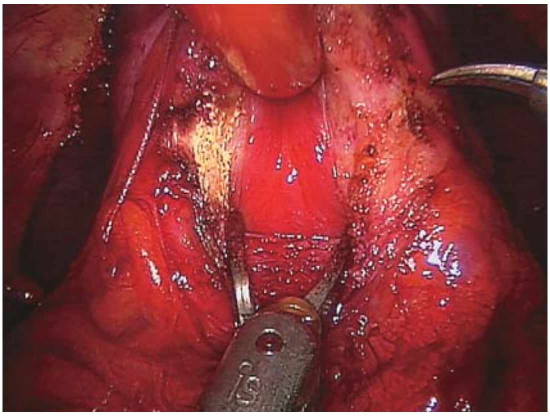

FIGURE A.11. Identification of the posterior bladder neck drop off.

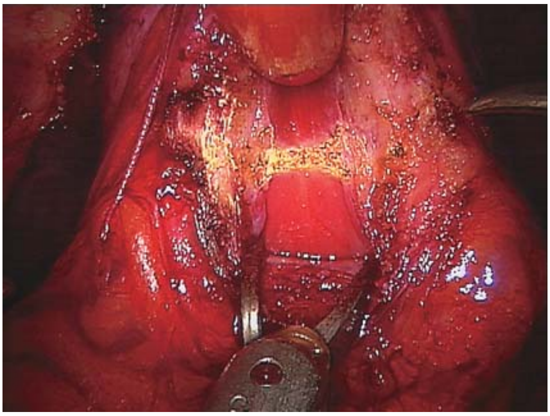

FIGURE A.12. Midline full-thickness incision of the posterior bladder neck.

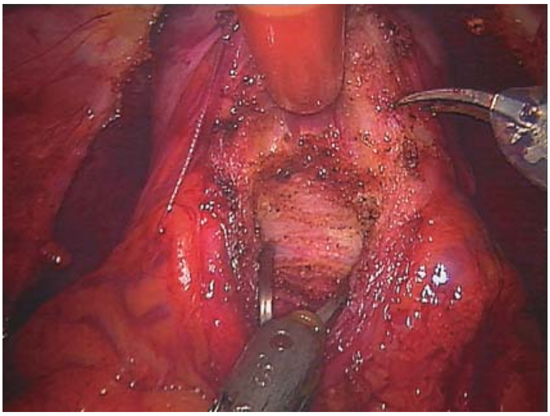

FIGURE A.13. Locating the sweet spot between prostate and bladder neck, an avascular plane leading directly to the seminal vesicles.

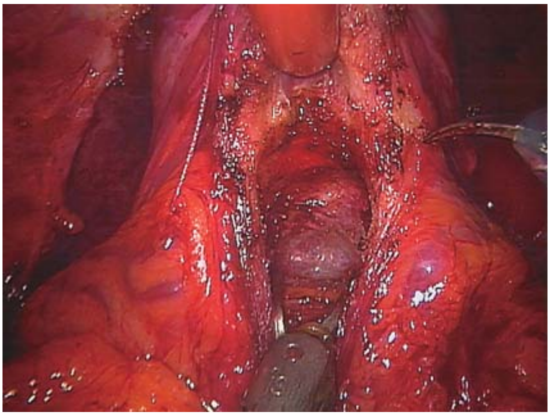

FIGURE A.14. Early identification of seminal vesicles.

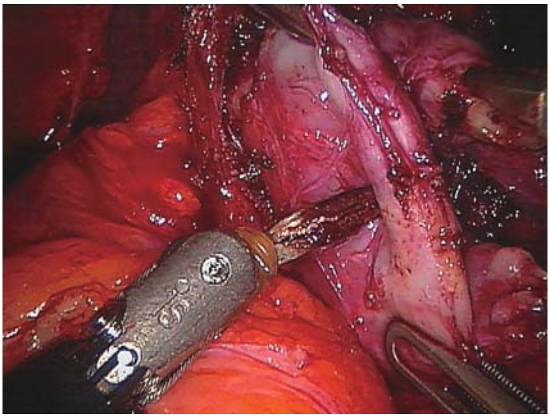

FIGURE A.15. Identification of vas deferens.

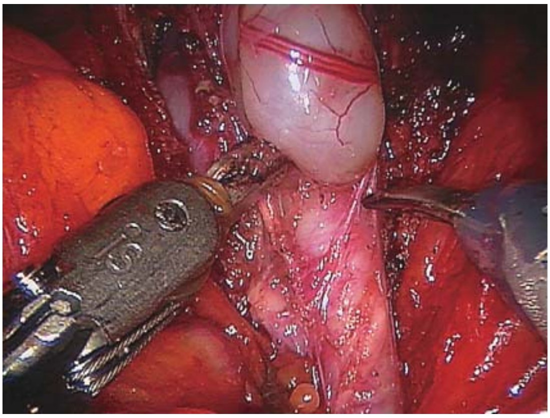

FIGURE A.16. Seminal vesicle dissection.

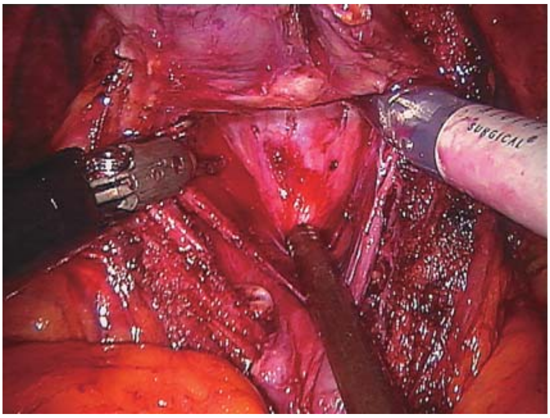

FIGURE A.17. Incision of Denonvillier's fascia.

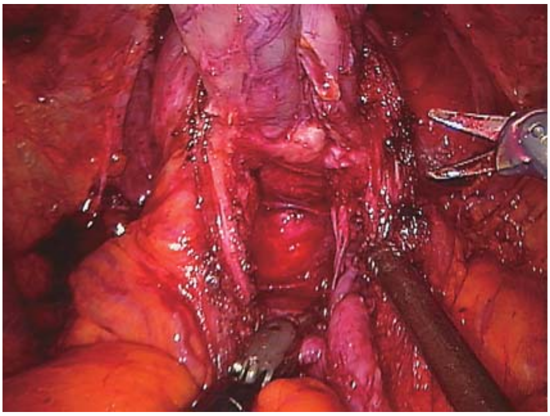

FIGURE A.18. Dissection of the posterior space.

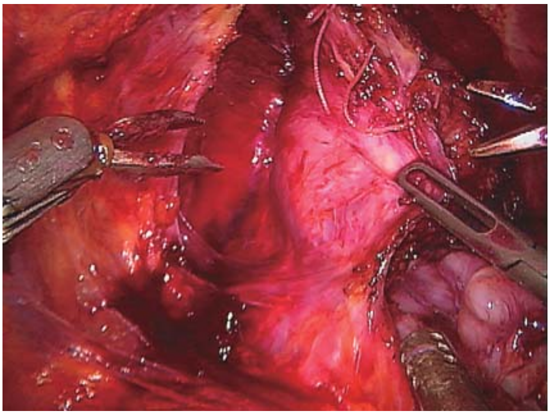

FIGURE A.19. Lateral rotation of the prostate.

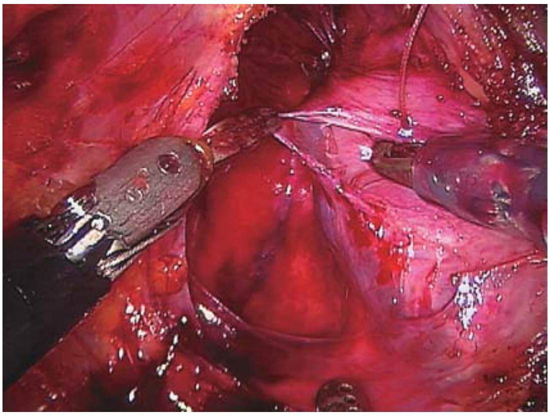

FIGURE A.20. Incision of the prostatic fascia.

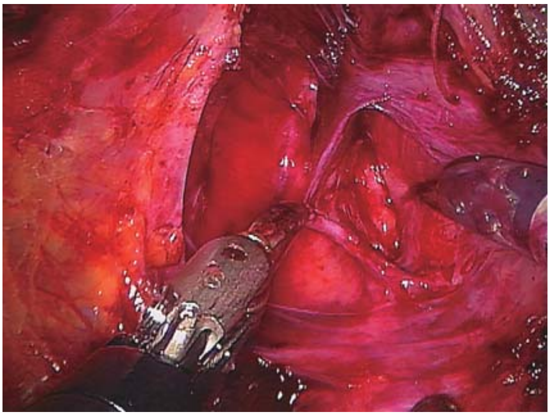

FIGURE A.21. Early apical identification and release of the neurovascular bundle (NVB).

FIGURE A.22. Retrograde dissection of the NVB.

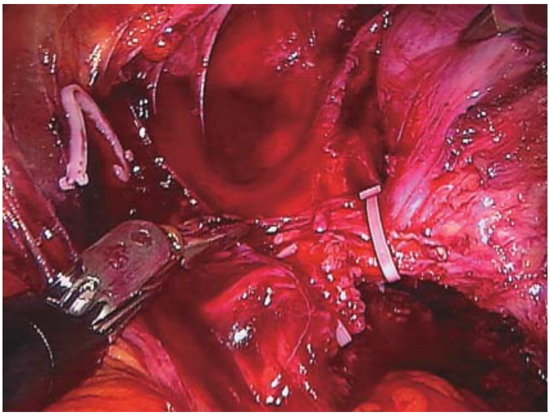

FIGURE A.23. Ligation of the prostate pedicle after clear identification of the path of the NVB.

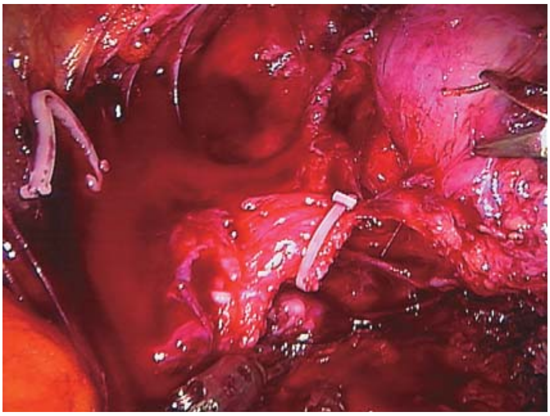

FIGURE A.24. Ligation and release of the prostate pedicle.

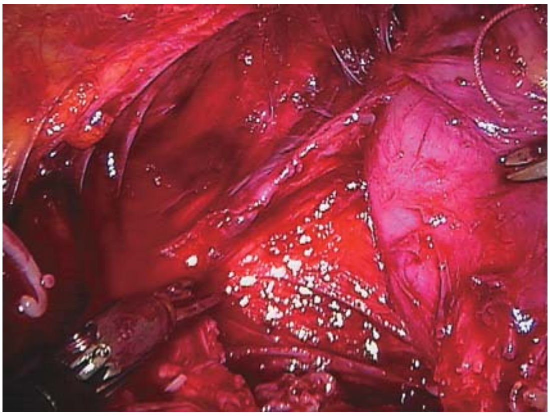

FIGURE A.25. Released NVB with a clearly identified path to the apex.

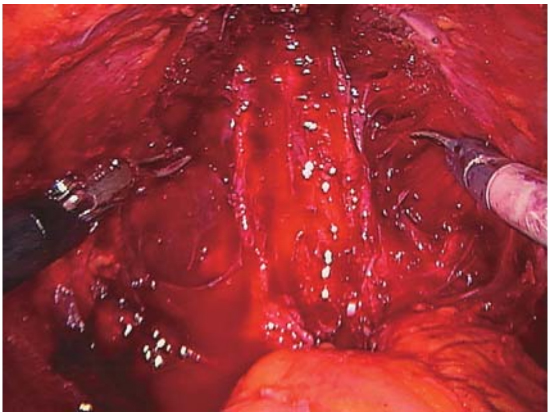

FIGURE A.26. Bilaterally preserved NVBs evident after prostate removal.

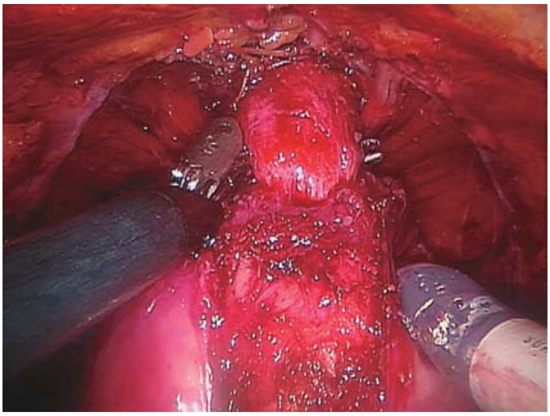

FIGURE A.27. Apical dissection and identification of the urethra.

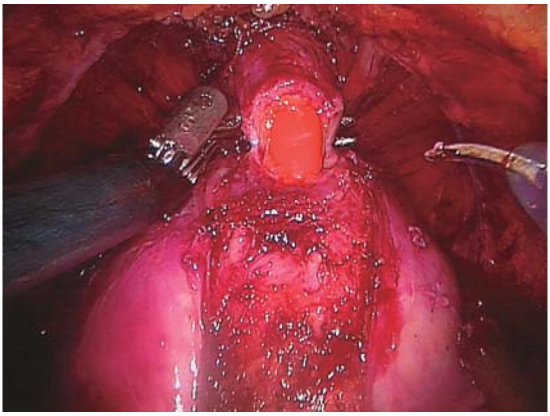

FIGURE A.28. Visualization of a long urethra stump.

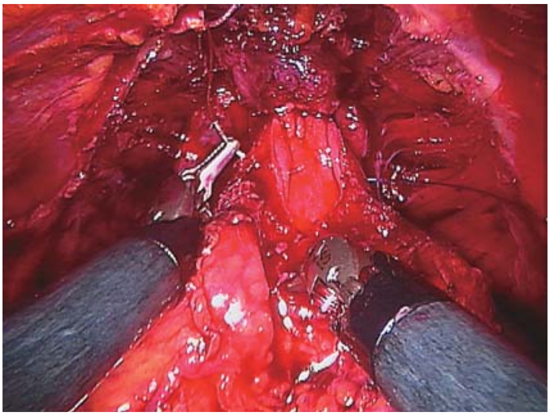

FIGURE A.29. Urethrovesicle anastomosis.

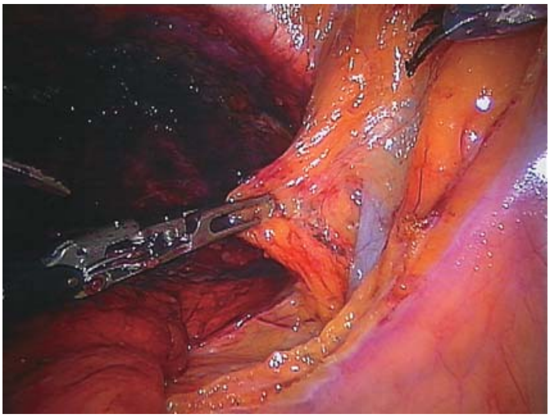

FIGURE A.30. Pelvic lymph node dissection.

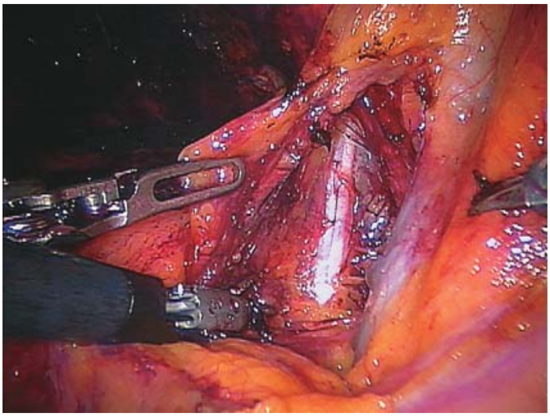

FIGURE A.31. Identification of the obturator nerve and iliac vein.

Appendix B
Pyeloplasty Images

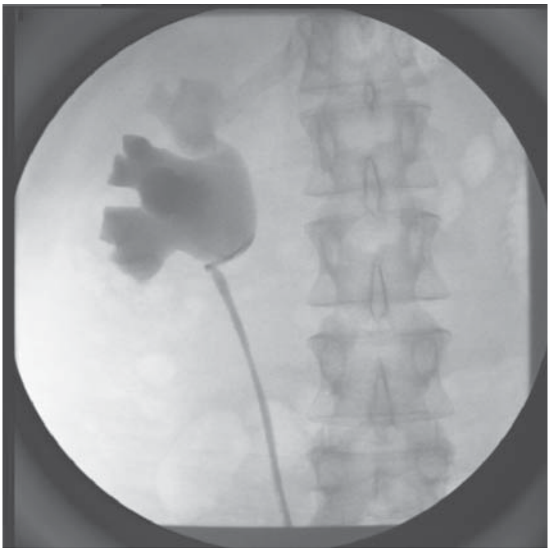

FIGURE B.1. Radiographic (retrograde pyelogram) representation of a ureteropelvic junction (UPJ) obstruction.

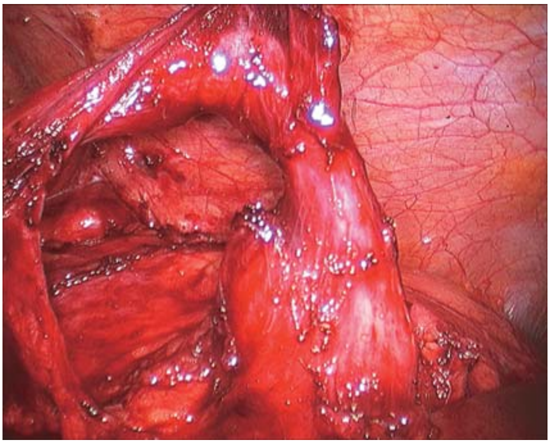

FIGURE B.2. Dissection and identification the ureter, renal pelvis, and area of obstruction (UPJ).

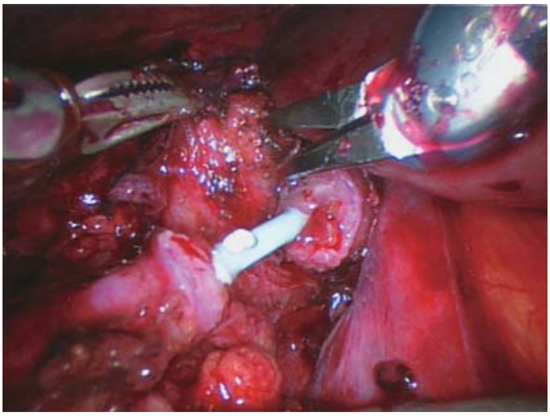

FIGURE B.3. Dismemberment of the UPJ with robotic scissors. The stent is visible in the lumen of the ureter and renal pelvis.

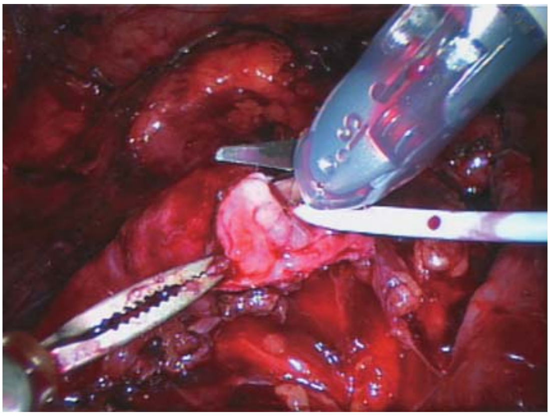

FIGURE B.4. Lateral spatulation of the ureter with the scissors beyond the area of obstruction.

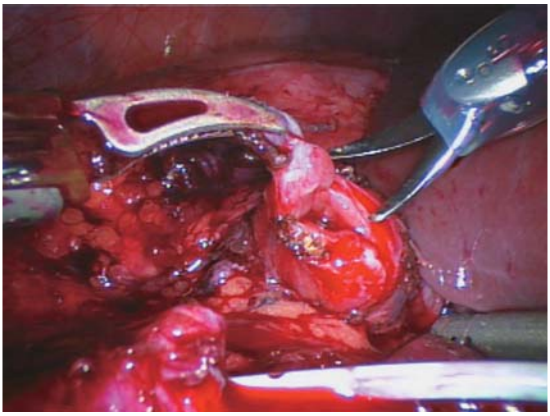

FIGURE B.5. Reduction and molding of the redundant renal pelvis.

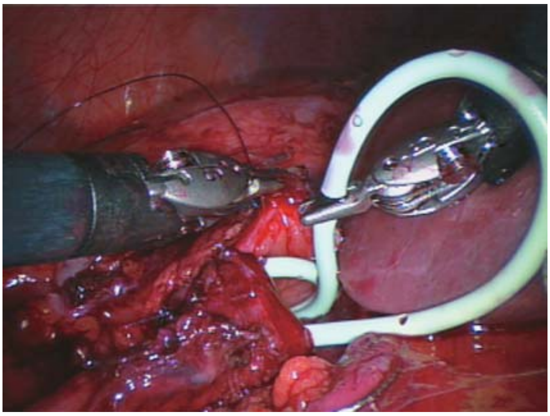

FIGURE B.6. Replacement of the stent into the renal pelvis using the robotic needle drivers.

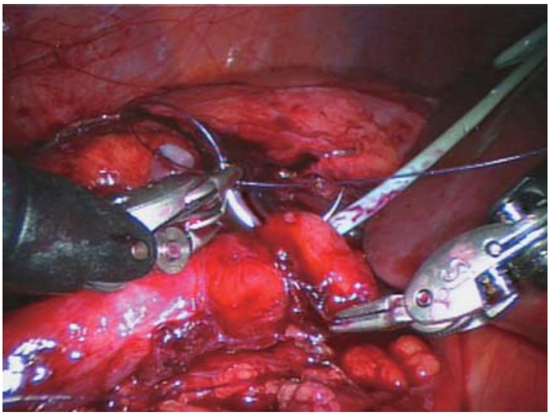

FIGURE B.7. Re-anastomosis of the ureter to the renal pelvis utilizing to hemi-circumferential running sutures.

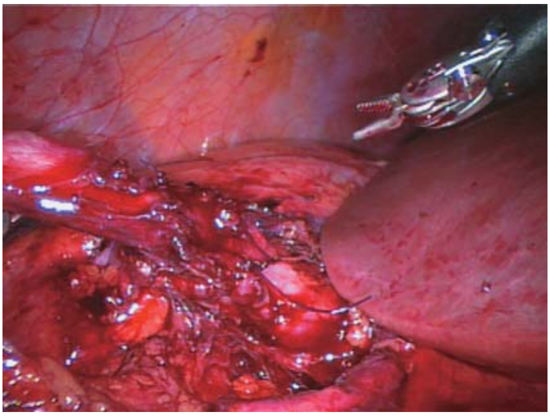

FIGURE B.8. The completed reconstruction of the UPJ.

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