Oncologic Telerobotic Surgery

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In Brief

Telerobotic surgical systems, such as the da Vinci™, overcome many of the specific shortcomings of traditional laparoscopic surgery and may shorten the learning curve for minimally invasive oncologic operations. Oncologic telerobotic applications include telerobotic radical prostatectomy, which is becoming the standard of care in many regions because of the dramatic impact on the surgeon's learning curve. In the future, telerobotic colectomy using a medial to lateral dissection might facilitate adoption of minimally invasive approaches to colorectal cancers. Other applications for oncologic surgery remain in early phases of development.

When initiating a new telerobotics program, surgeons should attend accredited training programs, use preceptors, and be judged by proctors before receiving surgical privileges.

Surgical approaches for cancer surgery rely on an implicit yet symbiotic relationship between surgical technique and technological development. Despite this essential dependency, practitioners of oncologic surgery remain hesitant to canonize minimally invasive approaches. Case in point:

Level I studies now show superior short-term outcomes and, at least, equivalent long-term outcomes for minimally invasive oncologic operations when compared to traditional surgical approaches.[1-4] Yet, today, few surgeons are performing laparoscopic colectomy for colon cancer or laparoscopic radical prostatectomy for prostate cancer. Why is this?

Advanced laparoscopic and thoracoscopic surgical procedures present daunting learning curves, which makes it difficult for many surgeons to introduce minimally invasive oncologic techniques into their practice. Among the challenges the surgeons face are the following:

- ***Past-pointing and disorientation.*** Traditional laparoscopy utilizes 2-dimensional imaging that promotes past-pointing, in which an attempted reach overshoots the target and the surgeon may become disoriented.
- ***Motion reversal.*** Laparoscopic instruments are straight, hampered by motion limitations, and introduced through trocars that act as a fulcrum. This causes motion reversal (i.e., the surgeon must depress the handle of the instrument to elevate the tip).
- ***Motion amplification.*** Typically, two thirds of the instrument is inside of the patient and only one third outside, generating a condition known as motion amplification. For example, a one-inch motion of the instrument's handle displaces the tip two inches. Similarly, any resting tremor the surgeon might have is amplified.
- ***Accelerated fatigue.*** Laparoscopy demands that the surgeon stand in awkward positions that accelerate fatigue and often lead to orthopedic injuries.[5]

Although some skilled surgeons overcome these obstacles, most surgeons find laparoscopic colectomy and laparoscopic radical prostatectomy, for example, too difficult to learn. Telerobotic surgical systems offer a solution to this problem.

Why Telerobotics?

The history of telerobotic surgery begins with The United States Army's hopes to develop a mechanism by which combat surgeons could operate from a remote secure location on wounded soldiers on the battlefield.[6] Using technology licensed from the Stanford Research Institute, IBM, and the MIT Robotics Laboratory, Intuitive Surgery (Sunnyvale, Calif.) developed the da Vinci™ telerobotic surgical system. During telerobotic surgery, the surgeon is physically separated from the patient and performs the operation using a computer console to control the remote robotic arms. In June 2000, the Federal Drug Administration (FDA) approved the da Vinci system for use in all abdominal operations. Currently, the FDA requires that the surgeon and surgeon's control console are physically located within the same operating room as the patient. Although originally marketed for cardiac revascularization, clinicians now champion widening applications in cancer surgery.

Telepresence surgery refers to telerobotic surgery when the surgeon and control console are geographically separated from the patient and robotic arms. Although initially developed for telepresence combat surgery, telerobotic surgical systems may resolve the paradox between the demand of evidence-based medicine to perform minimally invasive oncologic procedures and the difficulty surgeons face in learning to safely perform advanced laparoscopic operations.

The da Vinci telerobotic surgical system addresses each of the inherent limitations to traditional laparoscopic surgery cited above. The da Vinci robot, although not automated to perform any portion of a procedure independently, allows an operator control of robotic hands at a distance and in a manner that provides greater precision[7] and ergonomically optimized control.[8,9]

With the da Vinci system, the surgeon views a true 3-dimensional virtual image of the patient's anatomy at the computer control station. The robotic tower supports four robotic arms. These arms connect to interchangeable surgical instruments that offer hand-like motions with seven degrees of freedom of motion. [To reach any possible point in space within its work envelope, a robot needs a total of six degrees

of freedom (X,Y,Z, yaw, pitch, and roll). The developer of the telerobotic surgical system defines the seventh degree of freedom as the function of the instrument itself, i.e., grasping or cutting.] Not only is the robotic wrist able to rotate, but it is capable of bending further and in more directions than a human wrist. There is no motion reversal. The computer filters out resting tremors and allows the surgeon to select various ratios of favorable motion scaling (e.g. 1-1, 3-1, or 5-1). Robotic motion scaling allows more precise movements which are typically made more difficult by resting tremor and the fulcrum effect. The surgeon sits in an ergonomically comfortable position at the control station.

Together, these features greatly shorten the learning curves of procedures such as telerobotic radical prostatectomy.

Telerobotic Oncologic Applications

Prostate cancer is rapidly becoming one of the most commonly diagnosed cancers in men. Radical prostatectomy reduces disease-specific mortality in patients with localized prostate cancer; however, the invasiveness of surgery and its resultant side effects cause many men to seek other treatments. Studies have demonstrated the superiority of telerobotic radical prostatectomy over open approaches and its equivalence to laparoscopic radical prostatectomy. Operative times, blood loss, postoperative pain, and median times to urinary continence and resumption of sexual activity are reported as lower for robotic than for open or laparoscopic radical prostatectomy.[10] Robotics use the same incision sizes as laparoscopy, and—as stated above—telerobotic surgery is easier for surgeons to master than traditional laparoscopic surgery. Telerobotics increases the number of surgeons capable of performing a minimally invasive prostatectomy and therefore makes the procedure available to a greater number of patients worldwide.

An experience of more than 1,100 robotic retro-pubic prostatectomies reports nearly equal oncologic results as traditional open retro-pubic prostatectomy but with the advantages of a minimally invasive approach.[11] Similar results are reported when evaluating robotics in the community setting with a learning curve of approximately 20 to 25 cases. With a structured methodical introduction, robotics can be safely and effectively integrated into a community practice with minimal patient morbidity, and good oncologic and functional outcomes.[12]

As surgeons gain more experience with this new technology, even more complex urologic and gynecologic approaches are introduced. Additional extra-peritoneal approaches for the prostate, more closely approximating the standard open technique are likely to gain popularity.[13] Robotic ileal conduit urinary diversion is performed for patients with radiation cystitis as well as bladder cancer.[14] Preliminary experiments also demonstrate the feasibility of integrating robot-assisted technology in the performance of robot-assisted staging of gynecologic malignancies.[15]

Minimally Invasive Surgery Fighting for Rights to Gastrointestinal Cancer

In terms of colorectal curative resections, long-term results provide level I evidence that laparoscopic surgery for colon cancer provides equivalent oncologic outcomes and can be performed with equivalent morbidity and mortality rates when compared to conventional surgery.[1,2] Multi-center, randomized controlled trials demonstrate that while in the hospital, patients assigned to laparoscopic procedures, instead of open surgery, require fewer analgesics.[1,2] Recovery is typically faster as demonstrated by laparoscopic patients' shorter median hospital stay.[1,16] Techniques that provide decreased intraoperative blood loss and earlier recovery of bowel function do not compromise radicalism of resection as assessed by number of removed lymph nodes and length of resected bowel.[2] Although more controversial, short-term data with rectal cancer from experienced centers does not report inferior oncologic results with laparoscopic total mesorectal excision.[17,18]

Robot-assisted laparoscopic surgery proves to be as safe and effective as laparoscopic techniques in prospective studies for the treatment of colorectal diseases.[19] Weber and colleagues first reported telerobotic laparoscopic colectomy in 2002.[20] Small case studies demonstrate robot-assisted laparoscopic colectomy as a feasible and safe procedure although initially with increased operative time and expense.[21] Morbidity and hospital stay are comparable to those for the patients undergoing standard laparoscopic procedures with the initial increase in operative time reduced significantly after the first few cases.[22]

Robotics is especially well-suited to surgical approaches that require precise dissection deep in the pelvis as well as the medial to lateral approach for colonic resection. This technique of colonic

A da Vinci telerobotic surgical system pictured in a surgical suite.

resection, popularized in Europe, entails early ligation of the inferior mesenteric vein and a dissection carried between the peritoneal layers of the colonic mesentery. While 'medial to lateral' may ultimately prove to be a technically superior technique,[23] there is no decisive oncologic benefit and clinicians are still not able to demonstrate a benefit of early vascular ligation in the no-touch open technique.[24,25] In short, the medial to lateral approach with early ligation of the inferior mesenteric vein, a relatively new laparoscopic approach, might even satisfy those who have continued to support the "no-touch" technique. Telerobotic surgical systems may offer advantages that facilitate complex operations and permit a large proportion of surgeons, in the future, to introduce minimally invasive colorectal surgery into their practice.[26] At the present time, telerobotic resection of gastric cancer,[27] hepatic resections and pancreaticoduodenectomies [28] are largely experimental and only performed clinically at a limited number of institutions.

Training and Credentialing

The introduction of telerobotics into clinical practice raises issues comparable to those generated by the rapid introduction of laparoscopic cholecystectomy (gallbladder removal) in the late 1980s. A small number of industry-supported training centers are developing across the country. Hospitals must assume the responsibility and burden of the granting of clinical privileges for telerobotic surgery but in a standardized manner that is agreed to by a consensus of robotic surgical specialists.

Currently, most programs follow the guidelines of the Society of American Gastrointestinal Endoscopic Surgeons (SAGES) for granting clinical privileges for laparoscopic general surgery**.** Hackensack Hospital requires that regimented criteria be profiled prior to credentialing a surgeon for robotic procedures as well as ongoing monitoring of surgical outcomes.[29]

At Hackensack University Hospital, regimented criteria include:

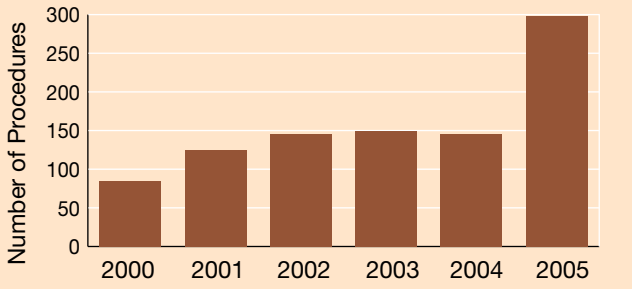
1. Board certified or board eligibility for the appropriate surgical board
2. Clinical privileges for the open and laparoscopic operation that will be performed telerobotically
3. Satisfactory completion of the FDA-mandated training course in the safe use of the robotic surgical system
4. Observation of an experienced surgeon performing telerobotic surgery
5. Performance of telerobotic operations in 5-10 animate models
6. Acting as bedside assistant surgeon in 5-10 telerobotic operations or supervision by a preceptor during the surgeon's initial 5-10 telerobotic operations
7. Observation by a proctor of 5-10 telerobotic operations
8. Ongoing monitoring of surgical outcomes of telerobotic operations.

Future Directions

Telerobotic remote surgery is now in routine use, providing high-quality laparoscopic surgical services to patients in a rural community and providing a superior degree of collaboration between surgeons.[30]

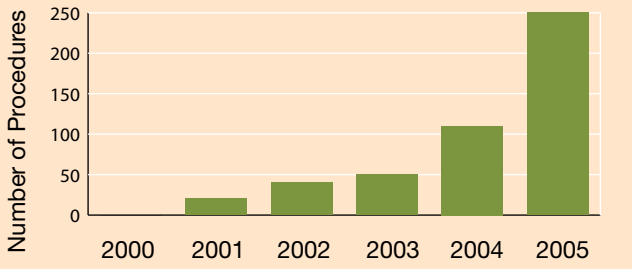
Although the robotic surgical system was originally designed to act as the hands and eyes of a surgeon operating from a considerable distance, benefits of true telepresence

Figure 1. Total Radical Prostatectomies at HUMC*



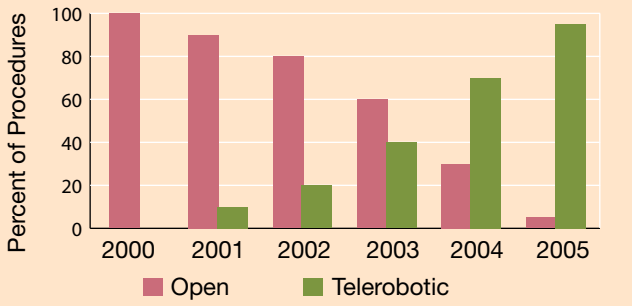
** 950 radical prostatectomies were performed from 2000-2005.*

Figure 2. Robotic Prostatectomies at HUMC*



**472 robotic prostatectomies were performed from 2000-2005*

Figure 3. Prostatectomies at HUMC*



** Total number of procedures from 2000-2005 = 950*

Source: R. Munver, I.A. Volfson, I.S. Sawczuk

remain largely hypothetical. A minimally invasive surgery center at McMaster University in Hamilton, Ontario can provide mentoring applications [31] that seem more practical than the transcontinental cholecystectomy[32] reported four years ago. Telepresence robotic mentoring might achieve increasing relevance as devices are introduced to community hospitals. The large majority of operations could be performed as routine with intraoperative telepresence tertiary care referrals for the very occasional hepaticojejunostomy or retropancreatic dissection.

Wristed instrumentation (i.e., articulated instruments with wrist-like movement) allows minimally invasive approaches that follow anatomic planes hypothetically with improved correlation to open techniques. In the future, evolving indications for the more precise application of brachytherapy may provide synergistic benefit with robotics and improved methods of localized resection. Robotics provide surgeons who initially trained

Telerobotics: Changing Practice Patterns

Not only does robotics allow minimally invasive resections that adhere to the oncologic guidelines created for the open operation, but practice patterns may also change as the device becomes more prevalent in the community.

Take, for example, the experience of Hackensack University Medical Center (HUMC) in Hackensack, N.J., a 781-bed teaching and research hospital and the largest provider of inpatient and outpatient services in the state of New Jersey. After evaluating nearly 800 radical prostatectomies performed by 14 surgeons over nearly five years, HUMC found an interesting trend directly related to the use of robotics in the treatment of localized prostate cancer. Although the laparoscopic option was always available, surgeons were very hesitant to attempt the technique and switch from their open practice. As more surgeons trained in robotic-assisted surgery, the trend gradually shifted away from open prostatectomy and towards robotic-assisted prostatectomy. Robotics also increased the total number of prostatectomies performed annually. The robotic surgical system allows surgeons to overcome the challenges of conventional laparoscopy, thus making minimally invasive radical prostatectomy a more widely available alternative to open surgery.[33]

with open techniques a minimally invasive platform to safely perform decisive oncologic resections.

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