Medical Robotics: The Impact On Perioperative Nursing Practice

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Howard N. Winfield

Medical robotics is revolutionizing medical care both inside and outside operating rooms. The field of surgery has not seen such innovation since the first laparoscopic cholecystectomy procedure was performed in 1985 (Reynolds, 2001). The market for minimally invasive surgery (MIS) procedures has been driven steadily higher by technological advances that have enabled physicians to provide surgical patients with numerous benefits including improved postoperative comfort and decreased pain, better cosmesis and quality of life, faster recovery, decreased hospital stay, quicker return to activities of daily living, fewer complications, and reduced cost (Himly et al., 2004; Lanfranco, Castellanos, Desai, & Meyers, 2004; Mack, 2001).

Medical robotics is used to enhance the performance of physicians during minimally invasive procedures (Taylor, Lavallee, Burdea, & Mosges, 1996). The number of procedures performed each year with robotic assistance is growing, as well as the number of surgical specialties using robotics (Chandra & Frank, 2003).

The nursing care that patients require has been affected by procedures being performed with a minimally invasive approach. For example, patient education strategies have been revised to do more teaching preoperatively, since patients are no longer hospitalized for 3 to 7 days postoperatively. Likewise, the creation of freestanding ambulatory surgical centers has helped shift the focus of nursing activities from inpatient to outpatient care. MIS has also impacted the nursing role by increasing the amount and complexity of technology support the operating room nurse must provide for these cases. Thus, it is important that nurses seek opportunities to educate themselves about this technology, assess its impact, and determine how to best care for patients in the future. This article contains a brief history of medical robotics, some background on reasons for robotic technology use, and the perioperative aspects of caring for patients undergoing robotically assisted surgery.

Medical Robotic History

Industrial robots evolved throughout the 20th century, and entered mainstream American life in 1961 when they were installed in the first automobile manufacturing line at a General Motors factory (ROVer Ranch, 2005). Medical robotic systems were slower to develop in a commercial capacity due to financial constraints (see Table 1). Some of the first medical applications for robotic technology to be investigated were in the fields of neurosurgery and orthopedics (Falcone & Goldberg, 2003; Gerhardus, 2003; Nathoo, Pesek, & Barnett, 2003).

Robotics entered the field of urology in the late 1980s with the application of a robotic arm, nick-named PUMA 560, for transurethral resection of the prostate (TURP) (Lanfranco et al., 2004). This early medical robot was approved for a limited clinical trial in humans (Satava, 2002; Taylor et al., 1996). It did not become a treatment of choice for TURP due to poor ultrasound
imaging capabilities of the prostate (Allaf, Patriciu, Mazilu, Kavoussi, & Stoianovici, 2004).

The next application for robotics in urology was in assisting the urologist with intra-operative percutaneous renal access. Many attempts to develop a highly precise, mechanical method of percutaneous renal access have led to a robotic surgical system that has been modified several times, but has now demonstrated an 87% accuracy rate in gaining renal access (Allaf et al., 2004; Kim & Schulam, 2004). An extended clinical trial of the robotic system demonstrated rates for the number of attempts, and time to renal access, which were comparable to the standard technique (Allaf et al., 2004). Further development and continued clinical trials are necessary to duplicate results demonstrating that this robotic surgical system can produce results comparable or better than the standard method of renal access (Allaf et al., 2004).

Through the mid to late 1980s, scientists at the National Aeronautics and Space Administration (NASA)-Ames Research Center were working on development of virtual reality and telemedicine technology (Satava, 2003). Virtual reality is defined as “the simulation of a real or imagined environment that can be experienced visually in the three dimensions of width, height, and depth and that may additionally provide an interactive experience visually in full real-time motion with sound and possibly with tactile and other forms of feedback” (Virtual Reality, 2005). Telemedicine is the concept of a physician monitoring, diagnosing, and treating a patient without physically being in the patient’s presence. Virtual reality technology connects the physician with the environment the patient is in, and allowing the physician the illusion of being present in this other environment, referred to as telepresence. Once telepresence has been achieved, medical robotics then allows the physician to manipulate the environment in which the patient exists without physically being present in that environment. Thus medical robotic technology is the key element in telemedicine that enables a physician to treat a patient without being physically present.

The NASA group teamed up with mechanical engineers working on robotics from Stanford Research Institute (SRI) to create telemedicine technology that allowed manipulation of the patient (Satava, 2003). A general surgery endoscopist (Richard M. Satava, MD), who was working for the United States Army, was introduced to the NASA and SRI teams after meeting one of the SRI team members at a conference. Dr. Satava made the U.S. Army aware of the NASA-SRI project, and its potential benefits for telemedicine on the battlefield (Satava, 2003). Realizing the possible applications of medical robotics and telemedicine, the U.S. Army directed a large amount of funding for research and development of medical robotic technology (Satava, 2003).

In 1989, Yulun Wang, PhD, a graduate engineer and acquaintance of Dr. Satava, founded his own medical robotics company with funding from the U.S. government and private industry. His company, Computer Motion, Inc.®, launched AESOP® (Automated Endoscopic System for Optimal Positioning), a robotic telescope manipulator, and the robotic surgical system ZEUS® (Marescaux & Rubino, 2003; Satava, 2003). AESOP was FDA approved for use in 1994, and is currently marketed in the United States (Marescaux & Rubino, 2003). Computer Motion, Inc. received FDA approval to market ZEUS in 2001 (Marescaux & Rubino, 2003).

In 1995, another physician with a keen business sense saw the commercial value of the

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>1921</td>
<td>Playwright (Karel Capek) describes robots as “dumb” machines for repetitive work in Rossum’s Universal Robots</td>
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<tr>
<td>1946</td>
<td>Computer development arises</td>
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<tr>
<td>1950-60s</td>
<td>Development of industrial robots</td>
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<td>1961</td>
<td>First industrial robot in use at GM automobile factory in New Jersey, called Unimate</td>
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<td>1985</td>
<td>First laparoscopic surgery performed (cholecystectomy)</td>
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<td>1980s</td>
<td>Puma 560 arm used for transurethral resection of the prostate</td>
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<td>1980s</td>
<td>Robotic arm assisted with intraoperative percutaneous renal access</td>
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<tr>
<td>Late 1980s</td>
<td>Stanford Research Institute working on robotics and telemanipulation</td>
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<tr>
<td>1989</td>
<td>Computer Motion Inc. formed (AESOP) Robotic arm designed to manipulate endoscope and camera during surgical procedure developed</td>
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<td>1995</td>
<td>Intuitive Surgical Inc. formed</td>
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<tr>
<td>2003</td>
<td>Computer Motion Inc. and Intuitive Surgical Inc. merge</td>
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Robotic Technology’s Improvement to Minimally Invasive Surgery

The benefits of MIS, as discussed earlier, for both the patient and the medical insurance providers are well documented (Hanly et al., 2004; Lanfranco et al., 2004). However, minimally invasive surgery has limitations that are obstacles surgeons must overcome. These same limitations prevent a minimally invasive approach to every type of open procedure (see Table 3).

The first limitation of MIS is the loss of three-dimensional vision of the human eye. Traditional laparoscopic camera systems provide surgeons with only two-dimensional vision. Robotic camera systems bond two telescopes and two camera heads together, side-by-side, and incorporate a synchronizer into the system (Marescaux & Rubino, 2003). This creates a right and left “eye,” which provides the primary operating surgeon with a three-dimensional view. Another method of providing a three-dimensional view is to place the operative image on a shutter screen, or on two monitors incorporated into a headset or glasses that the operative surgeon wears (Boehm, Detter, Arnold, Deuse, & Reichenspurner, 2003). This provides a much better view than that of the two-dimensional traditional laparoscopic/thoracoscopic cameras, by providing depth perception.

The second limitation of MIS is awkward ergonomics. Surgeons are required to stand, holding long instruments, in uncomfortable positions. Medical robotics allows the primary operating surgeon to sit while operating, and provides armrests. This greatly improves the primary operating surgeon’s ergonomics, and thus comfort (Stylopoulos & Rattner, 2003). Medical robotics improves the surgeon’s ergonomics even further, by creating a computer interface between the surgeon’s hands and the instrument tips. This translates the natural/intuitive movement of the surgeon’s hands into the desired movement of the robotic instrument, bypassing the handle and shaft of the laparoscopic instrument (Stylopoulos & Rattner, 2003).

Robotic technology provides...
the means to overcome many of the limitations of MIS, while also providing improved dexterity for surgeons. This is accomplished in four ways. First, the robotic instruments themselves have five to seven degrees of freedom of movement compared to the four degrees of freedom of movement in traditional laparoscopic/thoracoscopic instruments (Ballantyne & Moll, 2003; Boehm et al., 2003). Second, the computer in the robot eliminates the fulcrum effect, which in traditional laparoscopic/thoracoscopic surgery creates the need for the surgeon to move his/her hand in the opposite direction in which the tip of the instrument is intended to go. As mentioned previously, the computer creates an interface that bypasses the laparoscopic/thoracoscopic instrument handle and shaft, and translates the natural movements a surgeon’s hands make to the instrument tips, with corrections for the fulcrum effect. Third, the robotic computer is also programmed to filter out the physiologic tremor in the human hand, which can be greatly magnified at the end of a very long instrument. Finally, robotic computers allow the surgeon to choose to scale, either up or down, the ratio of the size of the movement of his or her hands to the movement at the instrument tips (Ballantyne & Moll, 2003).

All of these capabilities make

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Table 3.
MIS vs. Robotic Advantages and Disadvantages

<table>
<thead>
<tr>
<th>MIS Advantages</th>
<th>MIS Disadvantages</th>
<th>Robotic Advantages</th>
<th>Robotic Disadvantages</th>
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<tbody>
<tr>
<td>2-D visualization only</td>
<td>Poor ergonomics for surgeon (craning head to see TV and hold long instruments)</td>
<td>Improved ergonomics: Surgeon sits, arm rest, surgical movements are intuitive</td>
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<tr>
<td>Enables some tactile feedback</td>
<td>Compromised dexterity: Fulcrum effect, magnification of tremors, only four degrees of freedom of movement</td>
<td>Improved dexterity: 7 degrees of freedom of movement, fulcrum effect eliminated, physiologic tremors eliminated</td>
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<td>Cheaper technology (at this point in time)</td>
<td></td>
<td>Motion scaling: (Surgeon’s hand: robot instrument tip) 1:1 3:1 5:1</td>
<td>Initial cost of systems</td>
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<tr>
<td>Research base compiled to prove efficacy</td>
<td></td>
<td></td>
<td>Lack of research base on efficacy</td>
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<tr>
<td>Identified procedures best used for</td>
<td></td>
<td></td>
<td>Need to identify best uses for technology</td>
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<tr>
<td>Sufficient number of cases to train surgeons and support staff</td>
<td></td>
<td></td>
<td>Insufficient number of cases to train residents and support staff</td>
</tr>
<tr>
<td>Many operating rooms incorporating MIS needs into design</td>
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<td>Large size of systems</td>
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Source: Adapted from Lanfranco et al., 2004
medical robotics ideal for MIS procedures that require very fine or difficult dissection, intracorporeal suturing, high magnification, or surgery on small infants or children. Thus, robotic surgical systems are valuable in assisting surgeons in performing many MIS procedures with greater ease. It also enables a surgeon to perform MIS procedures that may be too difficult to perform with a traditional laparoscopic/thoracoscopic approach (Tooher & Pham, 2004).

The daVinci surgical system was intentionally built to immerse the surgeon in the operative field by using a viewer for the surgeon that is the same as looking through a microscope (Ballantyne & Moll, 2003). The surgeon can hear what is occurring in the operating room, but must remove his or her face from the viewer to see what is occurring in the operating room. The Zeus system places the surgical view in front of the operating surgeon as if it were a television show. The surgeon can also see what is occurring in the operating room by turning his/her attention from the screen.

Both the daVinci and ZEUS surgical systems are referred to as “master-slave” systems (Ballantyne & Moll, 2003; Boehm et al., 2003; Lanfranco et al., 2004). This refers to the principle that the robotic surgical system is dependent on human motion directed into it through some type of interface such as a joystick or mouse so as to generate any movement of the robotic arms and instruments. The robot computer itself does not generate any movements. These systems are really just an extension of a surgeon’s hands and fingers.

This should not, however, lull medical professionals or the consumer into a false sense of security. These systems require highly trained personnel to operate, setup, and maintain (Connor, Reinbolt, & Handley, 2001). Every health care professional involved in the utilization of a robotic surgical system has the potential, through human error, to cause an unwanted outcome. The chance of this happening can be greatly reduced by providing education and training to all personnel involved in operating, setting up, and maintaining a robotic surgical system (see Figure 1).

Figure 1. Robotic Surgical System

PERIOPERATIVE CARE OF ROBOTIC SURGERY PATIENTS

Pre-Operative Care

Pre-operative care of the robotic surgical patient population differs only slightly from pre-operative care of the non-robotic MIS patient population (laparoscopic/thoracoscopic surgery). Pre-operative care instructions should be given in writing, and reviewed with the patient verbally (Alexander, 1999; Davison, Moore, MacMillan, Bisaillon, & Wiens, 2004; Lithner & Zilling, 2000). Attention should be given to consistency between the written and verbal instructions (Otte, 1996), and identification of any patients who do not have literacy skills adequate to comprehending the written material (Alexander, 1999). For all patients undergoing MIS, regardless if it is robotic or not, the same pre-operative functions of assessment, planning, implementation, and evaluation are carried out. The patient’s level of anxiety or fear should be assessed. Additionally, pre-operative teaching content should be adjusted to address any issues associated with the patient’s attitudes and feelings related to the MIS procedure and its outcome (Hathaway, 1986). If the nurse is able to lessen the patient’s level of anxiety or fear through discussion of these issues, or having misconception corrected, there will be a higher retention level of material on specifics of postoperative care and medications. The overall content of the educational program does not need to be altered for patients, but modifying the order of things presented, or the time they are presented for each patient, may create a better learning environment (Hathaway, 1986).

Patients undergoing robotically assisted procedures have the same need for education on what to expect postoperatively for pain, activity level, possible complications, and care of their surgical site. They also have
questions about the robotic procedure and surgical system. Currently the only available patient education materials related to robotic surgical procedures are generic resources from the manufacturers. Robotic surgery is being talked about in the media in relation to its cutting-edge technology. However, very little is actually being circulated to educate the layperson on how medical robotic systems function, and what role they play in health care. Clearly more detailed information for patients is needed to ensure their understanding of this treatment option, and to facilitate their decision making.

The word robot can conjure up images of Star Wars’ C3PO, or the more recent movie, I Robot. It can be very intimidating to patients to think they are giving up control of their medical care to a machine. For this reason it is important for them to understand the master-slave relationship of the robotic surgical system to the surgeon. Emphasis should be placed on the fact that the robotic surgical system is a tool used by the surgeon to perform surgery, and not a medical device that is preprogrammed or acts on its own. It is also important for the patient to understand the reasons for the use of this technology (see the previous section: Robotic Technology’s Improvement to Minimally Invasive Surgery), and appreciate that the surgeon feels using the robotic surgical system in their case is beneficial.

Intra-Operative Care

Intra-operative nursing functions are affected the most by medical robotic technology. Nursing personnel must know how to properly connect, calibrate, and setup the equipment pieces of the surgical robotic system. They must also be familiar with the robotic instrumentation needs for each type of procedure, including how to properly load, handle, and clean these specialized instruments. The nursing personnel should also understand the robotic system well enough to know how to troubleshoot problems for the primary/non-sterile operative surgeon at the robotic surgical system and the surgeon at the patient’s side. The patient-side surgeon assists the primary/non-sterile operative surgeon by exchanging sterile instruments, retracting patient tissues, and manipulating non-robotic sterile instruments used to assist the procedure.

The ability of the nursing personnel to interpret and react to messages displayed on the robotic television monitor is critically important to the flow and success of the procedure, and allows the surgeons to focus fully on the surgical procedure. It is sometimes necessary to abort a robotic MIS procedure for reasons of bleeding, unexpected anatomical findings at the time of surgery, or a surgeon’s decision that the patient’s anatomy is not best accessed by MIS. For these reasons nursing personnel in the operating room must also be familiar with emergency procedures for removing the robotic system from the patient’s side, and assembling the necessary equipment, instruments, and supplies in order to move to the equivalent laparoscopic or open procedure.

Assigning one additional staff member to the case efficiently facilitates introducing a robotic surgical system into an operating room. This provides the necessary person to move, setup, and monitor the robotic system; while allowing the other two staff members to focus on the patient, and the sterile instrument setup. Once staff members are trained and familiar with procedures it is possible to perform robotic procedures with two staff members, depending on where the robotic surgical system is stored, and how much time and assistance they are given to set procedures up.

Postoperative Care

Postoperatively, patients undergoing robotically assisted surgery need to be treated with the same standards and care that patients undergoing the same non-robotic minimally invasive procedure would receive. Postoperative care should be tailored to the patient’s specific expected surgical outcomes.

However, hospital stays may be shortened for patients undergoing robotically assisted procedures when compared to open procedures. Earlier postoperative discharge decreases the amount of time there is for patient education, and increases the responsibility perioperative nurses have in patient education (Fox, 1998). Shorter postoperative hospital stays also necessitate changes in the content, method, and timing of postoperative patient education.

Patient education content must change to include material necessary for care of the patient at home during the first 3 days postoperatively. Earlier postoperative discharge places an additional responsibility directly on the patient and/or their home care attendant for care relating to recovery from anesthetic agents, recovery of full gastrointestinal and urological function, and management of postoperative pain, complications, and activity level appropriate for the first 48 hours postoperatively (Fox, 1998; Marley & Swanson, 2001). For patients, “recovery” is defined as the return to a pre-operative level of performing activities of daily living (Kleinbeck & Hoffart, 1994). It is estimated that 60% or more of outpatients required 3 days before they were able to return to their pre-operative level of activities of daily living (Philip, 1992). Discharging patients on postoperative day 1 or 2 makes it criti-
cally important that perioperative nurses ensure that patients understand how to transition back to their pre-operative lifestyles.

Patients can become overwhelmed with the amount of material being presented to them in a shortened time span, especially when their level of functioning is compromised from anesthesia, pain medications, and stress. This makes it even more important to assess the educational needs of each patient, and his/her ability at any specific time to assimilate and comprehend new information. A patient experiencing postoperative nausea/vomiting is ready and may be able to learn techniques for coping with, and reducing nausea/vomiting, but is not prepared and/or interested in learning how to care for his or her incision site(s).

Providing postoperative care instructions in written form and allowing for adequate time for patient review give patients time to formulate questions and enhances understanding of the content (Lithner & Zilling, 2000). Any written educational material must also be followed up by specific verbal instructions, in non-medical terms, that are consistent with the written material (Alexander, 1999; Fox, 1998; Lithner & Zilling, 2000). Presenting verbal instructions creates an opportunity for patients to ask questions. The verbal educational session should also be used to assess the patient’s literacy level, and understanding of the written material (Alexander, 1999).

Future Direction of Medical Robotics

Medical robotic surgical systems certainly will not be used for every type of surgical procedure, or on every patient. The extra cost of the system, instruments, disposable supplies, and personnel costs necessitate that medical robotic applications be carefully evaluated with respect to patient outcomes. Current medical robotic users are developing their skills, and searching for surgical procedures that have increased patient benefits such as increased surgical accuracy, decreased operating times, shorter hospital stays, and fewer complication rates when compared to the standard current surgical approaches.

Medical robotics is a growing and developing technology that will undergo many changes as its use evolves and is refined. Many institutions are currently attempting to add a “fourth arm” to their robotic surgical systems. In addition to the two robotic arms that hold and manipulate the surgical instruments that perform surgery, and a third robotic arm that holds and manipulates the telescope/camera that provides for visualization inside the patient, this fourth arm would provide the operating surgeon with a third arm which can hold an instrument to retract patient tissues or a suture. This provides the operating surgeon with more flexibility in maneuvering patient tissues to access the surgical site, without depending on the assistance of the patient-side surgeon; and it enables the operating surgeon more accuracy in retracting, and can also sometimes decrease operating times.

In the future, two surgeons will be able to control robotic arms on the same system, and swap with each other what arm they control. This will allow the assistant surgeon the same three-dimensional view and seven degrees of freedom of movement to the operating instruments being used (Ballantyne & Moll, 2003). Also, training simulators using virtual reality technology will be available to enable the surgeon to develop basic skills for use with robotic surgical systems, as well as practice a certain procedure on a computer-generated image of a particular patient’s anatomy before actually performing the procedure in the operating room (Ballantyne & Moll, 2003; Lemke et al., 2002).

Development of a three-dimensional capable “image shift” endoscope is underway. This endoscope system will allow a surgeon to go from a magnified view of specific anatomy, to a wide-angle view of the whole surgical field, without moving the telescope (Lemke et al., 2002). It will also increase patient safety by enabling the surgeon to easily and quickly visualize the whole surgical field, while maintaining a more accurate ability for the surgeon to visualize specific anatomy better than with the human eye. Additionally, the development of haptic and force feedback technology will allow surgeons to experience tactile and pressure sensation feedback in their hands, which is not possible with robotic surgical systems currently in use (Lemke et al., 2002).

Finally, the U.S. military has designed and field tested a new transport system called Life Support for Trauma and Transport (LSTAT) (Hudson & Grimes, 2002). LSTAT is essentially a mobile intensive care monitoring system incorporated into a transport bed that is being tested for use on a battlefield. Commercial applications may be found for this system in the future, in high-tech operating rooms where the patient is placed on an LSTAT at the beginning of his hospital stay, and travel from the operating room to recovery or an intensive care unit on the same bed (Satava, 2002; 2003).

Adapting to New Technology

Robotics is entering the medical world in more areas than the operating room. Robots are invading pharmacies, chart control, and certain aspects of home
care nursing (Sussman, 2000). It is important for nurses to embrace this technology, and use it to clarify nursing functions. Failure to recognize the impact of this technology on nursing practice will compromise the chance to guide our future and define the role of nursing in the health care technology revolution. However, in utilizing this technology and becoming masters of it, we can carve out a new niche for ourselves. As nurses, we can maintain the patient focus in this high-performance, automated, and sometimes cold world of technology by focusing on solid nursing principles of assessment, planning, implementation, and evaluation to provide compassionate, nurturing care with attention to patient safety. Adhering to the basic tenets of nursing practice will enable us to retain the human side of caring, but with the advanced knowledge necessary to ensure successful outcomes from MIS procedures. We must work hard to educate and train ourselves on all the new technology that enters our workplace, while at the same time recognizing and seizing the opportunities that lie ahead.

References


