ROBOTICS
IN MINIMALLY INVASIVE SURGERY

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The operating room, like many other areas of medicine, is a place of innovation and change. Technological advances demand that staff maintain currency with the newest and latest as technology changes and improves patient outcomes. While many of us are familiar with stereotactic neurosurgical interventions and the use of the Gamma knife, the most recent introduction into the operating room setting is the concept of the Intelligent Operating Room™.[1] This operating room of the millennium will revolutionize not only how the OR is staffed, but how procedures are performed. Practitioners have long lamented the introduction of the technology associated with minimally invasive surgical interventions, due to the myriad of machinery, wires, buttons, and knobs that all seem to need attention at the same time. The millennium OR is designed to organize and manage the intraoperative coordination of man and machine.

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b ackground

For years, robots have been used in manufacturing to assemble everything from automobiles to circuit boards, due to their ability to perform routine, repetitive tasks within a consistent tolerance and with a precision unable to be duplicated by the human hand. Some of this technology was introduced to the OR in the 1990s in the form of laparoscopic surgery. Unfortunately, the complexity of the human body—from the perspectives of both the patient and the surgical staff—have been difficult to duplicate and manipulate. Laparoscopic instruments and monitoring equipment were not ergonomically placed in the OR suite. Instruments were cumbersome and didn't allow the surgeon to "feel" the environment through a sense of touch. Plus, they had a limited range of motion—four degrees of freedom versus the human hand's seven degrees of freedom. Visualization was also a problem, providing a two-dimensional view of a three-dimensional patient. And, it required additional staff to try to hold video equipment steady during the procedure.[7]

In the millennium OR, robotic concepts of consistency and precision can be utilized to assist surgeons in their performance of intricate minimally invasive surgical interventions with greater speed, accuracy, repetition, and cost efficiency.[2] Three emerging technologies are overcoming the challenges of the earlier laparoscopic technique: the robotic arm, the OR suite voice activation control system, and the remote surgical manipulator.

The robotic arm

The robotic arm is an automated device that is attached to the rail of the operating room bed (Figure 1). Its position permits the arm to rotate through a circular arc. The distal end of the arm has the ability to be attached to a telescope or a variety of surgical instrumentation similar to other minimally invasive instrumentation. At its point of attachment to the surgical telescope, the arm has the ability to articulate 360 degrees. The robotic arm is connected by cables to a computer, which sends messages to the arm, guiding its movements.

The commands for movement of the arm come from the surgeon by means of a foot pedal or a headset and transmitter worn under the surgical gown. When using the headset control, the surgeon's voice commands are first preprogrammed into a computer terminal, where a card records the surgeon's voice, intonation, pronunciations, and accents. The voice activation system "sleeps" during normal conversation, and is awakened by the surgeon calling its name before giving a command.

Through voice control, the surgeon can ask the robotic arm to move up, down, left, right, in or out; to save up to three different pictures and return to these pictures; and to move at three predetermined speeds. When in the activation mode, the master control unit can follow two basic sets of commands: those requiring continuous movement until commanded to stop, and those that achieve individual incremental movements which must be repeated.

This technology has several advantages over its predecessors.

- Use of the robotic arm allows safer and more secure movement of the scope. Because the program can return the scope to certain programmed positions during the intervention, the surgical staff can conserve time, effort, and motion.
- In its most simplistic form, the arm is attached to a telescope for manipulation of the visual field during minimally invasive surgery, freeing up additional surgical staff members.
- Not only does the arm hold the telescope for long periods, it also provides scope stability by eliminating the motion commonly associated with manual scope manipulation. This unnecessary movement can lead to a sense of motion sickness in the viewing staff.
- In its more complex form, the robotic arm can become an extension of the surgeon's hand, performing tissue dissection, manipulation, and suturing.

The most popular technology on the market today is found in Computer Motion's AESOP 3000™, the Automated Endoscopic System for Optimal Positioning.[3]

The OR suite voice activation control system

The second component to the surgical robotics team, the OR suite voice activation control system, consists of a master control unit, which may be hand-activated or programmed to respond to the commander's voice. The surgeon or assistant sends commands to the control unit through a headset and microphone. The unit then controls not only the robotic arm, but a multitude of other command-response controlled equipment in the OR suite, including the shaver and fluid pump in arthroscopic surgery, the light controls in the suite, or the printer and computer for storage of intraoperative photographic documentation. The master control unit is also programmed to ignore casual conversation, eliminating undesired responses. The HERMES™ System, also developed by Computer Motion, networks OR-specific equipment, such as tables, lights, cameras and surgical instrumentation. The surgeon controls these devices through voice commands or a hand-held touch-screen pendant in the operating field (Figure 2).[4]

The remote surgical manipulator

The remote surgical manipulator brings with it unprecedented technology and application for the realm of surgical intervention. The surgical manipulator consists of several robotic arms controlled from a common console. Attached to each arm is a vast array of surgical instrumentation, similar in concept to that used in today's minimally invasive procedures. In this procedure, however, the instrumentation handles are designed to articulate with and be manipulated by the robotic arms. The surgeon performs the procedure through a remote console by placing his or her hands on micromanipulators that feel and move in a similar manner to hand-controlled instrumentation. As the surgeon's hands move, the computer translates the received messages and manipulates the robotic arms and instrumentation in a manner that imitates the surgeon's every movement. The surgeon watches the activity on a three-dimensional screen in the console.

This technology also eliminates some of the earlier problems with laparoscopic surgery.

- The computer program is able to filter out hand tremor, permitting accurate placement of fine sutures and needles.
- It can also proportionally reduce the effect of hand motions so that the surgeon can suture in a confined space using the same motions he or she would use to perform the procedure (Figure 3).

FIGURE 1

The voice-controlled AESOP Robotic arm

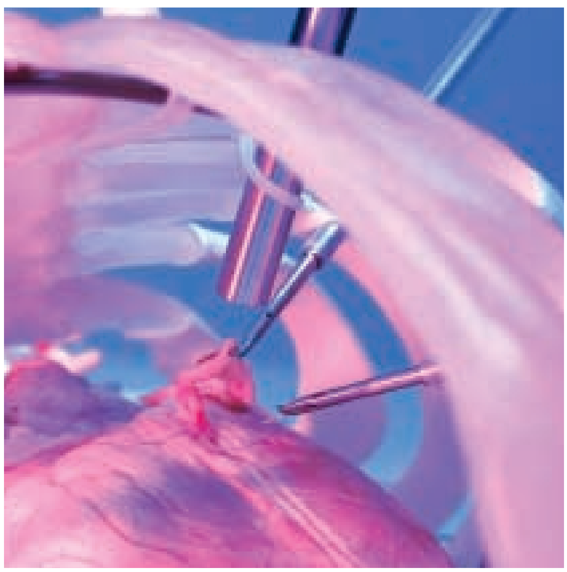
FIGURE 2

The HERMES System is activated through voice commands or a hand-held touch-screen pendant

- Better visualization of the surgical field is permitted, due to three-dimensional imaging and the streamlined design of the instruments.
- This multiple-arm technology can perform complex interventions in confined spaces via small access ports. Researchers predict that access port size will diminish as this technology become more commonplace, with 1.5 mm access ports becoming routine.[5]
- Finally, this technology gives surgeons the ability to perform telesurgery—a patient in one location is operated on by a surgeon in a remote location. The surgeon may be as close as a console in a room adjacent to the OR suite, or as distant as half way around the world. Not only does this application benefit small, remote hospitals, but could be used to protect the patient and OR staff in cases of highly infectious diseases.[6,7]

FIGURE 3

ZEUS Robotic Surgical System can proportionally reduce the effect of the surgeon's hand motions



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Remote surgical manipulators promise to make minimally invasive surgeries easier, quicker and more routine. They will open doors to a wider variety of difficult procedures and to the development of new minimally invasive procedures.[6]

ZEUS™ Robotic Surgical System

The ZEUS™ Robotic Surgical System is one such product available on the market today. This device, developed by Computer Motion, is currently under an FDA-approved Phase I Investigational Device Exemption (IDE) study and is available for commercial sale in the European Community.

The da Vinci™ Surgical System

In 1999, Intuitive Surgical introduced the da Vinci Surgical System™ and EndoWrist™ instrumentation. Similar to Zeus™, the da Vinci console permits remote location operation. Like the tendons in your hands and modeled after the human wrist, the EndoWrist instruments allow the surgeon to operate through 1 cm ports, while maintaining the capabilities and flexibility seen in traditional instrumentation. This technology is capable of enhancing or enabling a wide variety of procedures in many surgical specialties, including general, gynecological, thoracic, vascular and cardiac surgery.[6] This technology is also undergoing clinical trials in the US, but is fully approved in Europe.

Applications

Robotics is being introduced into a variety of surgical applications. From the stereotactic-guided brain biopsy and tumor ablation to the use of robots to ream the acetabulum and femur for total hip arthroplasty, robots are fast becoming an integral part of the surgical armamentarium. One of the most exciting and revolution-

Benefits of using robotics in the OR

- better staff utilization
- 24-hour-a-day availability
- documented time and cost savings
- reduction of scheduling conflicts and costly overtime charges
- streamlined procedures
- improved data management
- direct control of a motionless operative field of view to the surgeon
- enhanced dexterity and precision
- useful for a broad range of surgical disciplines
- reduction of the pain, trauma and recovery time associated with more invasive procedures[3,5]

Beating Heart E-CABG Case Study

The following is an abstract of Beating Heart E-CABG performed by Doctors Falk and Aybek at the Leipzig Heart Center in Leipzig, Germany.

History

A 48-year-old male patient presented with angina on exertion over the last 6 months. A stress ECG revealed significant ST changes in the anterior leads indicating ischemia of the anterior wall. Coronary angiography revealed a proximal 80 percent type-C lesion of the left anterior descending (LAD) artery that was not considered appropriate for angioplasty. The patient was scheduled for a single-vessel beating heart bypass.

Procedure

A totally endoscopic (five 1 cm incisions) beating heart bypass was performed on January 14, 2000, using the da Vinci™ Surgical System. A left side approach was used with 1 cm port placements at the 3rd, 4th and 7th intercostal spaces (ICS). An assistant port was placed at the 4th ICS and an endoscopic mechanical stabilizer with articulating pads was placed through a 10 mm sub-xyphoidal port. Once the stabilizer was in place, silastic loops were put in place to occlude the vessel and present the arteriotomy site. An assistant utilizing an additional arm of the da Vinci™ Surgical System, provided countertraction of the perivascular tissue during dissection of the target vessel, arteriotomy and suturing of the anastomosis. The anastomosis was performed in a parachute technique using 7-0 double armed Prolene suture. An irrigation channel in the instruments provided a bloodless field during suturing. Intraoperative angiography revealed a patent graft.

Postoperative course

The patient was transferred to the ICU and extubated 6 hours after surgery. On postoperative day 2 the patient was in the transitional unit and in the normal ward on day 3. The patient was discharged 6 days after surgery with an uneventful remaining postoperative course. The patient was able to resume normal activity on the day of discharge.[9]

An Endoscopic Clinical Case Study: Beating Heart CABG, used with permission of the Leipzig Heart Center, Germany, and Intuitive Surgical.

ary applications for this new technology, though, comes via the performance of beating heart e-CABG, endoscopic coronary artery bypass grafting. During this cardiac revascularization procedure, the left internal mammary artery is taken down and anastomosed to the coronary artery. The anastomosis is performed with the heart beating, with stabilization of the anastomotic site achieved using a suction device referred to as an "octopus." Not only does the fact that this can be performed via a minimally invasive approach, using three to five ports placed in the lateral chest wall, but the fact that this can be performed on the beating heart is significant, since cardioplegia carries with it significant mortality and morbidity. (See Beating Heart E-CABG case study.) Patients of tomorrow may, indeed, undergo coronary artery surgery on a day-surgery basis.

Conclusion

"The word 'robot' evokes many different thoughts and images, perhaps conflicting ones. Some may think of a metal humanoid, others of an industrial arm, and yet more may think, unfortunately, of a lost job."[5] However, the impact for surgical technologists and their knowledge base is clear. Surgical technologists will not only be required to prepare the arm for inclusion in the sterile field, but will be responsible for troubleshooting, positioning, and changing instrumentation. In some institutions, as the surgeon breaks scrub from the sterile field, the scrub and assistants may become the personnel responsible to exchange, load and manipulate items within the sterile field.

Though still in its infancy, the use of computer-enhanced and robotic systems provides surgeons with enhanced dexterity and precision to enable improvement in existing minimally invasive procedures and the potential to develop new minimally invasive procedures currently not possible. The use of robotics within the surgical arena can reduce the pain, trauma and recovery time associated with many of today's minimally invasive surgical interventions.[3] The day of robotics in the operating room is here. The millennium has arrived!

FIGURE 4

EndoWrist instruments from Intuitive Surgical now have almost total range of movement

About the author

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1. Problems with laparoscopic technology include ____.

a. two-dimensional visualization
b. limited range of motion
c. cumbersome instruments
d. all of the above

2. At its point of attachment, the robotic arm can rotate _____ degrees.

a. 90 b. 180 c. 45 d. 360

3. Which is not true about voice-activated robotic technology?

a. surgeon can control the arm's movement, speed and memory
b. surgeon's voice and intonation is prerecorded
c. foreign accents or odd pronunciation may trick the computer
d. the robot sleeps during normal conversation

4. Which of these cause/effect pairs are mismatched?

a. range of movement/fewer instruments
b. long-term stability/motion sickness reduction
c. secure movement/staff time and effort saved
d. stability and movement/staff freed up

5. The OR suite voice activation control system cannot control ____.

a. lights b. computer data storage
c. tables d. anesthesia machine

6. Access ports of the future will likely be ____.

a. 1.5 cm b. 1.5 mm
c. 1.5 inches d. none of the above

7. Which of these cause/effect pairs are mismatched?

a. multiple arm technology/complex interventions
b. three-dimensional imaging/reduced visualization
c. hand-tremor reduction/accurate suture and needle placement
d. remote console/better infection control

8. Remote manipulators will ______.

a. make minimally invasive surgeries more routine
b. provide options for small or remote hospitals
c. reduce the spread of infectious diseases
d. all of the above

9. With this technology, which is not true about the beating heart E-CABG?

a. performed without a heart/lung machine
b. uses an "octopus" suction device
c. uses only six access portals
d. none of the above

10. In the case study, the patient was able to resume normal activity _____ after surgery.

a. six days b. six weeks
c. 10 days d. 1 month

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3	❑	❑	❑	❑	8	❑	❑	❑	❑
4	❑	❑	❑	❑	9	❑	❑	❑	❑
5	❑	❑	❑	❑	10	❑	❑	❑	❑

Mark one box next to each number. Only one correct or best answer can be selected for each question.