ROBOTIC SURGERY

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INTRODUCTION TO ROBOTIC SURGERY

Circa 1941: Second World War; D-day, Normandy.

A soldier in a far off battlefield with a life threatening injury, with no doctor in sight for hundreds of kilometers. The nearest hospital is thousand kilometers away. He needs to be operated upon right away. He dies.

Now Imagine: An army ranger is riddled with shrapnel deep behind enemy lines. Diagnostics from wearable sensors signal a physician at a nearby mobile army surgical hospital that his services are needed urgently. The ranger is loaded into an armored vehicle outfitted with a robotic surgery system. Within minutes, he is undergoing surgery performed by the physician, who is seated at a control console 100 kilometers out of harm's way. The patient is saved. This is the power that the amalgamation of technology and surgical sciences are offering Doctors.

Just as computers revolutionized the latter half of the 20th century, the field of robotics has the potential to equally alter how we live in the 21st century. We've already seen how robots have changed the manufacturing of cars and other consumer goods by streamlining and speeding up the assembly line. We even have robotic lawn mowers and robotic pets now. And robots have enabled us to see places that humans are not yet able to visit, such as other planets and the depths of the ocean. In the coming decades, we will see robots that have artificial intelligence, coming to resemble the humans that create them. They will eventually become self-aware and conscious, and be able to do anything that a human can. When we talk about robots doing the tasks of humans, we often talk about the future, but the future of Robotic surgery is already here.
WHAT IS ROBOTIC SURGERY?

Robotic surgery is the latest technological advancement that introduces the robotic technology in the field of surgery. Only recently have robotic systems made their way into the operating room as dexterity-enhancing surgical assistants and surgical planners, in answer to surgeons' demands for ways to overcome the surgical limitations of minimally invasive laparoscopic surgery.

This system enables surgeons to remove gallbladders and perform other general surgical procedures while being seated at a computer console and 3-D video imaging system across the room from the patient. The surgeons operate controls with their hands and fingers to direct a robotically controlled laparoscope. At the end of the laparoscope are advanced articulating surgical instruments and miniature cameras that allow surgeons to peer into the body and perform the procedures. This system and other robotic devices developed or under development have the potential to revolutionize surgery and the operating room. They provide surgeons with the precision and dexterity necessary to perform complex, minimally invasive surgical (MIS) procedures, such as beating-heart single- or double-vessel bypass and
neurological, orthopedic, and plastic surgery, among many other future applications. Robotic surgery has broadened the scope and increased the effectiveness of minimally invasive surgery (MIS); improved patient outcomes; and created a safer, more efficient, and more cost-effective operating room. These Robotic systems will one day be applicable to all surgical specialties.
WHAT MAKES ROBOTIC SURGERY SO POWERFUL?

The Laparoscopic surgery—in which instruments are inserted through small incisions—has been used by surgeons whenever possible. Patients are less traumatized, require shorter hospital stays, and heal faster than with conventional surgery. Laparoscopic instruments are mainly limited to scissors and staplers to close incisions or attach blood vessels. It also has graspers to manipulate tissue. The instruments enter the body through a long tube; a video image from a tiny camera called an endoscope poked through another incision guides the surgeon. For a relatively simple procedure like gallbladder removal, the tools work well enough. But surgeons can't use the instruments to perform complicated tasks like suturing and knot tying. Because of these limitations, most operations can't be performed endoscopically.

Robotic surgery uses laparoscopic tools—including miniature robotic hands with the dexterity to tie knots. The reason the surgeons have to cut a person open is to get their hands in there. The surgeons like to get their hands around the organs, to palpate them. Robotic surgery provides with little instruments in there that let the surgeons feel as if they are working with their hands in a normal procedure, and hence avoiding a bigger incision.

The Robotic surgical system consists of a pencil-size joystick (one each for the surgeon's right and left hands), a computer, and right-hand and left-hand end effectors—the robotic instruments that snake into the body to perform the actual surgery. Each hydraulically powered end effector consists of a single digit, three to four inches long and less than half an inch wide. It has four joints that rotate, swivel, and swing back and forth and a grasper at the end. The result: A finger that functions like an entire hand. The surgery is completely anthropomorphic. If the hand moves in, the instrument moves in; if the hand moves to the right, the instrument moves to the right. The system also has force feedback, which relays to doctors the response of muscles and other tissues to their actions. The feedback makes the procedure feel more like normal surgery. The system also has tactile sensors that will transmit the feel of tissue to the surgeon's fingertips.
Surgery now uses robotic and image processing systems in order to interactively assist the medical team, both in planning the surgical intervention, and in its execution. This new technique enhances the quality of surgical procedures by minimizing their side effects (smaller incisions, lesser trauma, and more precision...), thus increasing patient benefit while decreasing the surgical cost. These techniques are being successfully introduced in several areas of surgery: neurosurgery, orthopedics, micro-surgery, cardiovascular and general surgery etc.
WHY GO FOR A ROBOTIC SURGERY?

The advantages of using robotic-assisted surgery are many:

• They bring down the cost of the operation.

• The patient has a faster recovery time because there is fewer traumas.

• There is less chance of complication.

• The doctor can see better through fiber optics than with his or her regular sight.

• Robotic arms do not suffer fatigue or tremors as do the human hand.

Some practical examples of the uses of robotic surgery are: -

> For instance, heart bypass surgery now requires that the patient's chest be "cracked" open by way of a 1 foot (30.48 cm) long incision. However, with some systems, it is possible to operate on the heart by making three small incisions in the chest, each only about 1 centimeter in diameter. Because the surgeon would make these smaller incisions instead of a long one down the length of the chest, the patient would experience less pain and less bleeding, which means a faster recovery.

> Robotics also decreases the fatigue that doctors experience during surgeries that can last several hours. Surgeons can become exhausted during those long surgeries, and can experience hand tremors as a result. Even the steadiest of human hands cannot match those of a surgical robot. For example, the da Vinci system has been programmed to compensate for tremors, so that if the doctor's hand shakes, the computer ignores it and keeps the mechanical arm steady.
ROBOTIC SYSTEM REQUIREMENTS

**Bandwidth:** This category of application, command and control usually requires relatively low bandwidth. This appears to be the case for the control of medical devices as well. The exception is the robotic surgery application which will require not just the transmission of control signals, but also the transmission of real-time motion images at VMS tape quality (about 75 Mbits/second).

**Latency:** Latency is the essential factor in these applications as the overshoot of a controlled parameter could result in a life-threatening situation. It has been suggested that the latency of the human nervous system is under 15 msec, and therefore the latency of the control system should be under 10 msec.

**Security:** These applications may involve the transmission of real patient data which the patient may consider sensitive or control signal which, if tampered with, could cause life threatening situations. They require a high level of transmission security to be sure that they cannot be viewed or altered during transmission.

**Reliability:** The network must be as close to 100% reliable as possible as lack of reliability could result in life threatening situations.

**Scalability:** This group of applications tend to be point to point applications and so will initially not require scalability. However, if viewed as a successful telemedicine applications, the bandwidth available on the network should be scalable so that the capacity can be increased in the future in response to potential increases in demand. In the case of robotic surgery, future additional interactive monitoring sites may be added so that such tele-surgery can also serve a useful teaching function which will require a degree of network scalability.
STEPS INVOLVED IN CONDUCTING SURGERY

There are two main steps in a general robotic surgery intervention:

1: **Data acquisition and subsequent planning:** In the pre-operative phase, a patient dependent model of the rigid, e.g. bones, and de-formable, e.g. the heart anatomical entities involved in the surgical act have to be built. For this, several medical imagery techniques, MRI, Scanner, Ultrasonic, etc. are used, where the anatomical structures are detected, located and modelled. In the same time, the mechanical model of the robotic system is fused in an overall geometric model. This will be used to describe and simulate the different potential problems that may occur during the intervention.
2: **Intra-operative assistance:** The results obtained in the planning phase are then calibrated and put in correspondence with patient in intra-operative situation. As a consequence, the robotic system is able to provide interactive assistance/guidance, and to constrain the movements of the surgeon in order to perform, with the desired precision, the possibly pre-defined procedure, e.g. neuro-surgical biopsy. In some cases, the robot may have an autonomous behaviour in order to realize a dedicated and fixed part of the procedure, e.g. thighbone drilling for artificial hip installation.

This is an illustration of a local robotic surgery unit.
**Surgeon console**- A high definition 3-dimensional image of the area to be operated upon is projected on to a screen. Mechanical controls for operating the robotic arm is handled by the surgeon in the console.

**Image processing equipment**- This consists of optical sensors and a Digital signal processor for getting enhanced images.

**Surgical arm cart**- This acts as a platform for the entire Robotic arm and is used for controlling the linear movements of the arm.

**Hi-resolution 3-D Endoscope**- This consists of an optical fibre and a reflector arrangement It is an optical instrument used for visual inspection or photography of internal parts of the human body. The insertion of the endoscope into the body is done either through the natural openings or through a small incision in the skin.

The Computer-Enhanced Surgical System which uses sensitive remote-controlled surgical instruments guided by a surgeon at a computer keyboard. The system involves using a tiny camera with multiple lenses inserted into the patient's chest, providing a three-dimensional image of the heart. The surgeon, at a nearby computer workstation, watches through a viewport to see inside the chest as a pair of joysticks are manipulated to control two precisely-engineered robotic arms.
The arms hold specially designed surgical instruments that mimic the actual movement of the surgeon's hands on the joysticks. Using the robotic technology, only three holes - each about the diameter of a pencil - are needed to complete the surgery. Sitting at the control console, a few feet from the operating table, the surgeon looks into a viewfinder to examine the 3-D images being sent by the camera inside the patient. The images show the surgical site and the two surgical instruments mounted on the tips of two of the rods. Joystick-like controls, located just underneath the screen, are used by the surgeon to manipulate the surgical instruments. Each time one of the joysticks is moved, a computer sends an electronic signal to one of the instruments, which moves in sync with the movements of the surgeon's hands.
So far, these machines have been used to position an endoscope, perform gallbladder surgery and correct gastroesophageal reflux and heartburn. The ultimate goal of the robotic surgery field is to design a robot that can be used to perform closed-chest, beating-heart surgery. According to one manufacturer, robotic devices could be used in more than 3.5 million medical procedures per year in the United States alone.
WHERE CAN ROBOTIC SURGERY BE USED?

Robots have often been thought of as machines that replace humans. These machines have been used in manufacturing, space exploration, and other areas. However, they can also be used as surgical tools. Many people think of these tools as devices used to replace the physician. However, they are used to complement human surgeons. Surgical robots are technical components in an overall system that allows the joining of information and action. "Surgical Robotics" refers to the application of "robotic" technologies, including sensing, manipulation, modeling and geometric analysis, and human-interfaces to increase human physicians' ability to carry out varied medical procedures.

There are increasing numbers of medical specialties that are using these technologies to extend and enhance human capabilities. Neurosurgery, orthopaedics, ophthalmology, dentistry, urology, general surgery, gynecology, radiation oncology, and many more fields are relying on robotics for a wide range of uses. This wide range of roles includes, "intern replacements", which perform such tasks as instrument holding, and limb positioning; "navigational aids", which help the clinician relate the "virtual" reality of presurgical images, models, and plans with the actual reality of surgery; "telesurgical systems", which extend the reach of the surgeon over great distances or into confined spaces; "precise positioning systems" which accurately place a needle, radiation beam, or other instrument onto selected targets, and "precise path systems", which move an instrument through a defined path.

The field of robotics provides an enhancement of human performance, the ability to project surgical expertise to remote and distant places, and recreation of a patient in a "virtual" form. Robotics takes the surgeon's motions and changes them into electronic signals which through a computer can be enhanced. The result is performing a procedure with greater accuracy and precision. Robotics allows doctors to perform the most delicate of operations with little risk and postoperative discomfort.
Robotic surgery has been used in many delicate procedures including heart surgery. The first coronary bypass surgery in a human patient using robotic arms manipulated by the surgeon was performed by Dr. Ralph Damiano, at the Milton S. Hershey Medical Center at Penn State College of Medicine in Hershey, Pennsylvania. The device, called the Zeus Robotic Surgical System, consists of three robotic arms that are used to manipulate instruments inserted into the chest through pencil-sized incisions. Normally, coronary bypass surgery requires a 12 to 15 inch incision in the chest, and patients are hospitalized for 5 to 6 days. This procedure may lead to the elimination of the large incision and to much faster recovery time. If robotic surgery continues to be safe and successful, it could mean that doctors many need to cut across the chest and crack the rib cage to perform open-heart surgery only in rare cases.

Because robotic instruments and controls are linked electronically via cable or satellite link, a surgeon can operate on patients located in remote areas. In order to perform a remote surgery operation, the system requires two functioning worksites: one for the surgeon and one for the robotic devices actually operating on the patient. Remote surgery is based on a master-slave robotics model, in which a controller manipulates the robot from a distance by using two joysticks that control the tracking of the robotic devices. The worksite on the patient's end contains the robotic devices, which perform the surgical procedures. Despite certain difficulties, many experts believe remote surgery will be a reality in a few years.

By providing the use of a variety of technologies to enhance the capabilities of human surgeons, robotics will become an increasingly vital component in the medical world. Doctors of the next century must learn to use this information to complement their capabilities in order to provide better patient care.
Researchers from SRI International and the University of Cincinnati will soon conduct the first robotic surgery in the history of mankind, in simulated zero gravity aboard a NASA C-9 aircraft that will take a route spanning 34,000 feet over the Gulf of Mexico.

The NASA C-9 is also known as the “weightless wonder” and will be able to simulate the microgravity that can be found in space. This zero gravity experiment will take into consideration the precision and speed where both human and robot surgeons will be able to cut and stitch an incision among other things. The SRI-developed software will also assist robot surgeons to compensate for “errors in movement” that is a very real possibility whether flying through space. Such robots will be able to be controlled remotely from thousands of miles away, and should the system be available commercially, it will enable patient care to begin the moment the ambulance door is closed. According to SRI’s Thomas Low. “In remote telesurgery, a surgeon controls a multi-armed robot located at the patient’s bedside from a distant location using a telecommunications network. This has the potential to provide emergency medical and surgical care to astronauts during space flights, soldiers injured in battle and patients living in remote regions on Earth where there are no physicians.”

THE FUTURE OF ROBOTIC SURGERY

Dept CSE, GECI Idukki
The future of robotic surgery is hard to believe but...it is now. If you haven't noticed, robotic surgery has come long ways and it was only a dream for doctors and engineers to have something that you no longer had to make big, hideous scars that would mess up somebody's body for the rest of their lives. Doctors, before robotic surgery, worked on making minimally invasive surgery that would take hours of surgery time. Now, surgery is still made in hours, but shorter hours are now in check with the robotic surgery. So you can't really say there is a future of robotic surgery, but you can say that this has been the future for doctors long ago so all you can say is...the future is now!!

The Future is now the field of surgery is entering a time of great change, spurred on by remarkable recent advances in surgical and computer technology. Computer-controlled diagnostic instruments have been used in the operating room for years to help provide vital information through ultrasound, computer-aided tomography (CAT), and other imaging technologies. Only recently have robotic systems made their way into the operating room as dexterity-enhancing surgical assistants and surgical planners, in answer to surgeons' demands for ways to overcome the surgical limitations of minimally invasive laparoscopic surgery, a technique developed in the 1980s.

On July 11, 2000, FDA approved the first completely robotic surgery device, the da Vinci surgical system from Intuitive Surgical. The system enables surgeons to remove gallbladders and perform other general surgical procedures while seated at a computer console and 3-D video imaging system across the room from the patient. The surgeons operate controls with their hands and fingers to direct a robotically controlled laparoscope. At the ends of the laparoscope are advanced, articulating surgical instruments and miniature cameras that allow surgeons to peer into the body and perform the procedures. This system and other robotic devices developed or under development by companies such as Computer Motion and Integrated Surgical Systems have the potential to revolutionize surgery and the operating room. They provide surgeons with the precision and dexterity necessary to perform complex, minimally invasive surgical (MIS) procedures, such as beating-heart single- or double-vessel bypass and neurological, orthopedic, and plastic surgery, among many other future applications.
Manufacturers believe that their products will broaden the scope and increase the effectiveness of MIS; improve patient outcomes; and create a safer, more efficient, and more cost-effective operating room. It is the vision of these companies that robotic systems will one day be applicable to all surgical specialties, although it is too early to tell the full extent to which they'll be used. Surgical robotics manufacturers working toward FDA approval of their devices are encouraged by Intuitive Surgical's recent FDA approval. "The future looks bright," says Yulun Wang, MD, founder and chief technical officer of Computer Motion. "This approval sends a positive signal to industry, and there are tremendous opportunities." According to Wang, "The goal of robotic surgery is to offer superior quality and reduced trauma to the patient. Today, the skeptical surgeon would say that's not proven yet, but the progressive surgeon would say that these goals are achievable. Thus far, the results have been phenomenal."

And many researchers and industry participants in the field say that the capabilities of first-generation systems are just the beginning. According to Richard E. Wood, MD, chief of cardiothoracic surgery at Baylor University Medical Center (Dallas), robotic surgery systems "will certainly make it easier to perform major surgeries, but these systems still need to evolve. They're not for every patient, but with time we will gain more experience and do more procedures, and the instruments will evolve from this first generation."

Currently, the three principal device manufacturers in this area are Intuitive Surgical, Computer Motion, and Integrated Surgical Systems. Their systems are described below. Future Outlook Surgeons and device executives agree that first-generation robotics systems have already displayed many advantages over traditional laparoscopic surgery and open surgery, especially in terms of speedier patient recovery and reduced pain. But they also insist that the technology is still evolving and will become more capable with time. "We're on the cusp of redirecting and improving surgical capability, but we are in the first generation of this process," says San Ramon's Gardiner. "The technology will be applied selectively early on, but as patients begin to insist on the new technology, it will become state-of-the-art and the standard of care for selected procedures."
Gardiner's opinion, as a general surgeon, "basically, the most promising applications for these systems will be in any surgery in which suturing is an important feature." Continued evolution of robotic surgical systems is inevitable, says Gardiner. "Down the road, as with PCs, the systems will become smaller, lighter, faster, and easier to set up, and this will increase their applications. As with CT scans, you will find uses and needs for the technology in excess of what the projections were, and surgeons will want and need these devices. The surgeon actually does a better, more precise, elegant, dexterous, controlled procedure with robotics, with less tissue damage, which leads to a better outcome."

"In the next five to seven years, almost all ORs worldwide will have robotic assistance of some kind for major surgeries," says ISS's Trivedi. "We will never, ever, replace the surgeon, but robotics will take over a lot of the things they do by hand, with more precision and accuracy." UCLA's Schulam, who has been using robotic surgical systems since 1995, when the first products were being developed, says that the elaboration of such systems may change the relationships between surgeons and industry. "Robotics are here to stay. However, it will take time for these devices to revolutionize the way surgery is done, and educational programs are the key to their success. "We need to change how industry and surgeons interact," he continues. "In the past, surgeons have had a consumer like relationship with the device industry, where the consumer buys the product and is off. But now, what will be required is a much more collaborative relationship, in order to get surgeons to change the way they're used to doing things." Baylor's Wood is even interested in forming a robotic surgery institute, perhaps within the next year, where surgeons from many specialties can meet and discuss how to bring robotics technology to the next level.

According to surgeons, patients have been asking about robotic surgery, and their feedback has been very positive. This demand is another key to the success of the robotics industry. "People are very informed today, because of the Internet," says Wood. "About 8% of my patients have asked about robotic surgery." "Frankly, I was very surprised," says Gardiner. "I thought patients would feel robotics is too impersonal, but I have found that not one patient has not wanted it."
CONCLUSION

The field of surgery has grown in amazing leaps and bounds since anesthesia was first developed and the first surgeries were performed, more than 100 years ago. Now, surgeons, through Robots are finding new ways to get inside the patient, rather than the standard large incision. The robotics revolution requires a different skill set and advanced instrumentation that can perform the functions of the human hand, but at a microsurgical scale. With the emergence of the first completely robotic surgery system, we are crossing the threshold into an amazing new future.

Surgical robotics systems mark the beginning of a potentially huge wave of surgical applications for robotic technology. With the assistance of surgical robots, surgeons can't extend their healing skills to places within the body that are currently out of reach. The continuing evolution of this technology holds the promise of immense benefits in healing that cannot yet be imagined.
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