ROBOTIC SURGERY

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ABSTRACT

The field of surgery is entering a time of great change, spurred on by remarkable recent advances in surgical and computer technology. 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. The first generation of surgical robots is already being installed in a number of operating rooms around the world. These aren't true autonomous robots, but they are lending a mechanical helping hand to surgeons. Remote control and voice activation are the methods by which these surgical robots are controlled. Robotics is being introduced to medicine because they allow for unprecedented control and precision of surgical instruments in minimally invasive procedures. The ultimate goal of the robotic surgery field is to design a robot that can be used to perform closed-chest, beating-heart surgery. Robots in the field of surgery have dramatically changed the procedures for the better. The most significant advantage to Robotic Surgery to the patient is the decrease in pain and scaring. The smallness of the incisions also causes many other advantages that make Robotic Surgery worth the risk. Besides the obvious rewards to the patient, Robotic Surgery is also very advantageous to the surgeon and hospital.
INTRODUCTION:

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. 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 may see robots that have artificial intelligence. Some, like Honda's ASIMO robot, will resemble the human form. They may 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 robotic surgery is already a reality. Doctors around the world are using sophisticated robots to perform surgical procedures on patients. While robotic surgery systems are still relatively uncommon, several hospitals around the world have bought robotic surgical systems. These systems have the potential to improve the safety and effectiveness of surgeries. But the systems also have some drawbacks. It's still a relatively young science and it's very expensive. Some hospitals may be holding back on adopting the technology. Robotic surgery is the use of robots in performing surgery. Three major advances aided by surgical robots have been remote surgery, minimally invasive surgery and unmanned surgery.
HISTORY:

In 1985 a robot, the PUMA 560, was used to place a needle for a brain biopsy using CT guidance. In 1988, the PROBOT, developed at Imperial College London, was used to perform prostatic surgery. The ROBODOC from Integrated Surgical Systems was introduced in 1992 to mill out precise fittings in the femur for hip replacement. Further development of robotic systems was carried out by Intuitive Surgical with the introduction of the da Vinci Surgical System and Computer Motion with the AESOP and the ZEUS robotic surgical system.

- In 1997 a reconnection of the fallopian tubes operation was performed successfully in Cleveland using ZEUS.
- In May 1998, Dr. Friedrich-Wilhelm Mohr using the Da Vinci surgical robot performed the first robotically assisted heart bypass at the Leipzig Heart Centre in Germany.
- In October 1999 the world's first surgical robotics beating heart coronary artery bypass graft (CABG) was performed in Canada using the ZEUS surgical robot.
- In 2001, Prof. Marescaux used the Zeus robot to perform a cholecystectomy on a pig in Strasbourg, France while in New York.
- The first unmanned robotic surgery took place in May 2006 in Italy.

ROBOTIC SURGEONS:

The first generation of surgical robots are already being installed in a number of operating rooms around the world. These aren't true autonomous robots that can perform surgical tasks on their own, but they are lending a mechanical helping hand to surgeons. These machines still require a human surgeon to operate them and input instructions. Remote control and voice activation are the methods by which these surgical robots are controlled. Robotics is being introduced to medicine because they allow for unprecedented control and precision of surgical instruments in minimally invasive procedures. 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. Here are three surgical robots that have been recently developed:

- da Vinci Surgical System
- ZEUS Robotic Surgical System
• AESOP Robotic System

CLASSIFICATION:
Not all surgical robots are equal. There are three different kinds of robotic surgery systems:
  • Supervisory-controlled systems
  • Telesurgical systems
  • Shared-control systems.

The main difference between each system is how involved a human surgeon must be when performing a surgical procedure. On one end of the spectrum, robots perform surgical techniques without the direct intervention of a surgeon. On the other end, doctors perform surgery with the assistance of a robot, but the doctor is doing most of the work.

There are mainly three telesurgical robotic systems namely da Vinci Surgical System, ZEUS Robotic Surgical System and AESOP Robotic System.

SUPERVISORY-CONTROLLED ROBOTIC SURGERY SYSTEMS:
Of the three kinds of robotic surgery, supervisory-controlled systems are the most automated. But that doesn't mean these robots can perform surgery without any human guidance. In fact, surgeons must do extensive prep work with surgery patients before the robot can operate. Dr. Scott J. Boley demonstrates a robotic surgery system at the Montefiore Institute for Minimally Invasive Surgery in New York City.

Fig :Demonstration
That's because supervisory-controlled systems follow a specific set of instructions when performing a surgery. The human surgeon must input data into the robot, which then initiates a series of controlled motions and completes the surgery. There's no room for error -- these robots can't make adjustments in real time if something goes wrong. Surgeons must watch over the robot's actions and be ready to intervene if something doesn't go as planned. The reason surgeons might want to use such a system is that they can be very precise, which in turn can mean reduced trauma for the patient and a shorter recovery period. One common use for these robots is in hip and knee replacement procedures. The robot's job is to drill existing bone so that an implant fits snugly into the new joint. Because no two people have the exact same body structure, it's impossible to have a standard program for the robot to follow. That means surgeons must map the patient's body thoroughly so that the robot moves in the right way. They do this in a three-step process called planning, registration and navigation In the planning stage, surgeons take images of the patient's body to determine the right surgical approach. Common imaging methods include computer tomography (CT) scans, magnetic resonance imaging (MRI) scans, ultrasonography, fluoroscopy and X-ray scans. For some procedures, surgeons may have to place pins into the bones of the patient to act as markers or navigation points for the computer. Once the surgeon has imaged the patient, he or she must determine the surgical pathway the robot will take. The surgeon must tell the robot what the proper surgical pathway is. The robot can't make these decisions on its own. Once the surgeon programs the robot, it can follow instructions exactly. The next step is registration. In this phase, the surgeon finds the points on the patient's body that correspond to the images created during the planning phase. The surgeon must match the points exactly in order for the robot to complete the surgery without error. The final phase is navigation. This involves the actual surgery. The surgeon must first position the robot and the patient so that every movement the robot makes corresponds with the information in its programmed path. Once everyone is ready, the surgeon activates the robot, which carries out its instructions.

**TELESURGICAL SYSTEMS**

**THE DA VINCI SURGICAL SYSTEM**

The basis of the dexterity experienced in open surgery relies on the almost unlimited wrist, elbow and shoulder’s degree of freedom. The degree of freedom in laparoscopic surgery is limited because instruments need to be long and are manipulated through fixed ports. The
surgeon has to move around these fixed ports. In order to solve these limitations tools have been
developed that have an articulation at the tip, which increases the degrees of freedom. Addition
of the wrist at the tip of the instrument gives tool manipulation much more complex. Computer
assistance is warranted, as the human brain cannot efficiently manipulate articulated instruments
by mechanical means. A robotic wrist provides articulated motions with a full 7 degrees of
freedom inside the abdominal or thoracic cavities. A product of the company Intuitive Surgical,
the da Vinci Surgical System is perhaps the most famous robotic surgery apparatus in the world.
It falls under the category of telesurgical devices, meaning a human directs the motions of the
robot. In a way, this makes the robot a very expensive high-tech set of tools. Types of
instruments used by the da Vinci Surgical System

![Fig: da Vinci surgical system](image)

On July 11, 2000, the U.S. Food and Drug Administration (FDA) approved the da Vinci Surgical
System for laparoscopic procedures, making it the first robotic system allowed in American
operating rooms. The da Vinci uses technology that allows the human surgeon to get closer to the surgical site than human vision will allow, and work at a smaller scale than conventional surgery permits. The $1.5 million da Vinci system consists of two primary components:

- A viewing and control console
- A surgical arm unit that includes three or four arms, depending on the model

It has four robotic arms. Three of them are for tools that hold objects, act as a scalpel, scissors, bovie, or unipolar or dipolar electrocautery instruments. The fourth arm is for a camera with two lenses that gives the surgeon full stereoscopic vision from the console. The surgeon is seated at a set of controls and looks through two eye holes at a 3-D image of the procedure, while maneuvering the arms with two foot pedals and two hand controllers. In using da Vinci for surgery, a human surgeon makes three or four incisions (depending on the number of arms the model has) -- no larger than the diameter of a pencil -- in the patient's abdomen, which allows the surgeons to insert three or four stainless-steel rods. The robotic arms hold the rods in place. One of the rods has two endoscopic cameras inside it that provide a stereoscopic image, while the other rods have surgical instruments that are able to dissect and suture the tissue. Unlike in conventional surgery, the doctor does not touch these surgical instruments directly. 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 or three surgical instruments mounted on the tips of the surgical rods. The surgeon uses joystick-like controls located underneath the screen to manipulate the surgical instruments. Each time the surgeon moves one of the joysticks, a computer sends an electronic signal to one of the instruments, which moves in sync with the movements of the surgeon's hands. Working together, surgeon and robot can perform complete surgical procedures without the need for large incisions. Once the surgery is complete, the surgeons remove the rods from the patient's body and close the incisions. The da Vinci System is FDA cleared for a variety of surgical procedures including

- Prostate cancer surgery.
- Hysterectomy.
- Mitral valve repair.
- Prostatectomies
- Cardiac valve repair
• Gynecologic surgical procedures
• Abdominal surgical procedures
• Thoracic surgical procedures

Surgeons are beginning to employ the da Vinci System to remove tumors on the liver and pancreas, on account of the delicacy of the procedure, the number of blood vessels that the surgeon must deal with, and the single location of the operation. Procedures that are not localized and require the surgeon to move around to different areas are very inconvenient, considering the time it takes to set up the da Vinci System's ports.

Fig: Instruments used in Da Vinci Surgical System
ZEUS ROBOTIC SURGICAL SYSTEM:
The ZEUS Surgical System is made up of an ergonomic surgeon control console and three table-mounted robotic arms, which perform surgical tasks and provide visualization during endoscopic surgery. Seated at an ergonomic console with an unobstructed view of the OR, the surgeon controls the right and left arms of ZEUS, which translate to real-time articulation of the surgical instruments. A third arm incorporates the AESOP® Endoscope Positioner technology, which provides the surgeon with magnified, rock-steady visualization of the internal operative field.

Fig: ZEUS SURGICAL SYSTEM
Peerless voice control capabilities allow the surgeon to precisely guide the movements of the endoscope with simple spoken commands, freeing the surgeon's hands to manipulate the robotic surgical instrument handles. ZEUS custom scales the movement of these handles and filters out hand tremor, enabling surgeons with greater capability to perform complex micro-surgical tasks. The ZEUS Surgical System features the following components:

- Video Console
- Primary Video Monitor up to 23"W x 23"D
- Flat Panel Monitor: with support for an additional flat panel

**Surgeon Control Console**
- Touch Screen Monitor
- Support Arms and Surgeon Handles
- Mounting Areas: for speakers; access to controller front panels; access to PC and HERMES™ control center; mounting shelves for housing Control Units

**Industry Standard Mechanism - easy sterilization**
- Incorporates mechanism design based on standard flushing port and push-pull rod technology, the same makeup as industry-standard endoscopic equipment. Provides easy sterilization.

**Instrument Reusability**
- Uses robust, reusable instruments, built to withstand the rigorous OR environment.

**Instrument and Port Size**
- Offers unparalleled precision through 3.5 to 5-mm instrument and endoscope accommodation.

**Wide Array of Instruments**
- Offers a suite of more than 40 ZEUS®-compatible instruments, available in a variety of shaft diameters, from industry leaders Scanlan, Storz and US Surgical.

**Quick Instrument Changes**
- Incorporates a quick-change mechanism to seamlessly swap instruments and safely guide the placement of the instrument tips.

**Console Placement**
- Provides total flexibility in overall console placement, easily converting from setup directly at the operating table to setup as a physically removed console.
Rapid Setup
- Takes less than 15 minutes to set up.

Visualization
- Designed to adapt to individual surgeon preferences in viewing modes, permits both 2D and 3D visualization and accommodates a wide variety of endoscopes and monitor setups.

Secondary Monitors
- Secondary flatscreen video monitors mount parallel to the main monitor to provide additional patient data including vitals, image guidance reference display and a redundant view of the operative field for use with SOCRATES™.

Profile
- Built lightweight for easy installation and flexible adjustment, ZEUS® maintains a low profile. Its twin instrument positioning arms adhere equally to this design imperative, allowing assistant to retract, suction and irrigate during surgery.

Operation
- A user-friendly, single foot pedal provides device engagement and disengagement. When engaged, specific controls are easily accessed using voice control and touch screen interfaces.

Microwrist Hand Controls
- MicroWrist form-fitting hand controls translate the surgeon's movements with precise scaling and hand tremor filtering.

Six Degrees of Freedom
- 4 Motorized
  - Up and Down
  - In and Out
  - Shoulder: Back and Forth
  - Elbow: back and forth
- 2 Floating
  - Forearm: back and forth - safety function: float away to avoid ramming something
  - Wrist
- 1 Fixed change in angle
  - Elbow Tilt (+/- 3 degrees)

**Scaling**
- Offers infinite motion scaling, without limitation to arbitrarily defined increments. Scaling adjustment can be accomplished using either touchscreen or voice command.

**Seating Accommodation**
- Ergonomic console and seat provides optimal surgeon comfort for long procedures

**Repositioning**
- During surgery, endoscopic and instrument positioning arms tilt with the operating table; this flexible design eliminates the need to readjust or recalibrate the arms.

**Re-Indexing**
- At any time, the foot pedal releases the clutch, allowing surgeons to relax and reposition (center and re-index) their hands and arms.

**Endoscopic Position Saving**
- Provides the powerful capability to save 3 different endoscopic positions, retaining x-y-x axis coordinates that can be quickly and easily returned to at any time.

**Voice Control**
- Voice control components leverage the advantages of a sophisticated overall communications paradigm: individual surgeon voice modeling; context sensitive tree command structure; limited vocabulary for error avoidance; voice and visual feedback on command success; compensation for ambient OR noise.

**Pendant Control**
- Device control and communications options are embedded also in ZEUS. portable pendant device, allowing flexible, duplicate control options that transcend the OR's sterile boundary.

**Mirror Redundancy**
- Uses mirror redundancy technology at a rate of up to 1000 times per second to ensure patient safety
AESOP ROBOTIC SURGICAL SYSTEM:
The AESOP system employs the assistance of the Automated Endoscopic System for optical position. AESOP was the first robot to be cleared by FDA for assisting surgery in the operating room. AESOP is much simpler than the da Vinci and Zeus system. It is used by the physician to position the endoscope of a surgical camera inserted into the patient. Voice activated software allow the physician to position the camera leaving her hands free. The AESOP robotic surgical system was very complex. So that it cannot be used in operating rooms.
SURGEON BENEFITS:

- Its enhanced three dimensional visualization provides the surgeon with a true three-dimensional view of the operating field. This direct and natural hand and eye instrument is similar to open surgery with all around vision and ability to 300m in and 300m out.
- Improved dexterity: It provides the surgeon with intensive operative controls.
- Greater surgical precision: It permits the surgeon to control the instrument with high accuracy. It can be simply controlled by the movement of instruments.
- Increased range of motion: Endowrist instruments are used in this surgical system. It has the ability to rotate the instruments more than 300 degrees through tiny incisions

SHARED-CONTROL ROBOTIC SURGERY SYSTEMS:

Shared-control robotic systems aid surgeons during surgery, but the human does most of the work. Unlike the other robotic systems, the surgeons must operate the surgical instruments themselves. The robotic system monitors the surgeon's performance and provides stability and support through active constraint. A nurse prepares a robotic surgery system for heart surgery. Active constraint is a concept that relies on defining regions on a patient as one of four possibilities: safe, close, boundary or forbidden. Surgeons define safe regions as the main focus
of a surgery. For example, in orthopedic surgery, the safe region might be a specific site on the patient's hip. Safe regions don't border soft tissues. In orthopedic surgery, a close region is one that borders soft tissue. Since orthopedic surgical tools can do a lot of damage to soft tissue, the robot constrains the area the surgeon can operate within. It does this by providing haptic responses, also known as force feedback. As the surgeon approaches the soft tissue, the robot pushes back against the surgeon's hand. As the surgeon gets closer to soft tissue, the instrument enters the boundary region. At this point, the robot will offer more resistance, indicating the surgeon should move away from that area. If the surgeon continues cutting toward the soft tissue, the robot locks into place. Anything from that point on is the forbidden region. Robotic surgeons can be intimidating -- they don't have the best bedside manner. Like the other robots we've looked at, shared-control system robots don't automatically know the difference between a safe region versus a forbidden region. The surgeons must first go through the planning, registration and navigation phases with a patient. Only after inputting that information into the robot's system can the robot offer guidance. Out of the three kinds of robot surgical systems, the telesurgical approach has received the most attention. The success of the da
Vinci Surgical System caught the attention of doctors and the media alike. We may see more examples of shared-control and supervisory-controlled systems in the future.

Notes: (a) Operating room setup with surgeon seated at the control console. The patient side manipulator consists of two manipulation arms and one camera arm. (b) The surgeon’s console with three-dimensional endoscopic viewer and hand controls. Images used with permission from Intuitive Surgical, Inc.

APPLICATIONS:

Cardiac surgery
Endoscopic coronary artery bypass (TECAB) surgery and mitral valve replacement have been performed. Totally closed chest, endoscopic mitral valve surgeries are being performed now with the robot. Irfan mulic was the first person to have this done to him.

Gastrointestinal surgery
Multiple types of procedures have been performed with either the Zeus or da Vinci robot systems, including bariatric surgery.

Gynecology
Robotic surgery in gynecology is one of the fastest growing fields of robotic surgery. This includes the use of the da Vinci surgical system in benign gynecology and gynecologic oncology. Robotic surgery can be used to treat fibroids, abnormal periods, endometriosis, ovarian tumors, pelvic prolapse, and female cancers. Using the robotic system, gynecologists can perform hysterectomies, myomectomies, and lymph node biopsies. The need for large abdominal incisions is virtually eliminated. It can also be used for tubal re-anastomosis, hysterectomies and ovary resection.
**Neurosurgery**
Several systems for stereotactic intervention are currently on the market. MD Robotic's NeuroArm is the world’s first MRI-compatible surgical robot. Surgical robotics has been used in many types of surgical procedures including complement-image-guided surgery and radiosurgery.

**Orthopedics**
The ROBODOC system was released in 1992 by the Integrated Surgical Systems, Inc. Surgical robotics has been used in many types of orthopedic surgical procedures including total hip arthroplasty: femur preparation, acetabular cup replacement, knee surgery and spine surgery.

**Pediatrics**
Surgical robotics has been used in many types of pediatric surgical procedures including: tracheoesophageal fistula repair, cholecystectomy, nissen fundoplication, morgagni hernia repair, kasai portoenterostomy, congenital diaphragmatic hernia repair, and others. On January 17, 2002, surgeons at Children's Hospital of Michigan in Detroit performed the nation's first advanced computer-assisted robot-enhanced surgical procedure at a children's hospital.

**Radiosurgery**
The CyberKnife Robotic Radiosurgery System uses image-guidance and computer controlled robotics to treat tumors throughout the body by delivering multiple beams of high-energy radiation to the tumor from virtually any direction.

**Urology**
The da Vinci robot is commonly used to remove the prostate gland for cancer, repair obstructed kidneys, repair bladder abnormalities and remove diseased kidneys. New minimally invasive robotic devices using steerable flexible needles are currently being developed for use in prostate brachytherapy.

**ADVANTAGES:**
Robots in the field of surgery have dramatically changed the procedures for the better. The most significant advantage to Robotic Surgery to the patient is the decrease in pain and scaring. By using cameras and enhanced visual effects, doctors can make the tinniest of incisions. The da Vinci and Zeus system each use “arms” to operate. In order for these arms to get inside the body and operate, they only need a few centimeters for an incision. In fact The San Matteo Hospital in Pavia, Italy performed a Cardiac Bypass surgery that included three incisions, each about one
centimeter in length. Typically in that type of surgery the incision is about 30 centimeters in length. The smallness of the incisions also causes many other advantages that make Robotic Surgery worth the risk. Due to the small and precise cuttings, the patient’s hospital stay is greatly reduced. A person needs far less recovery time when they have 3-centimeter scars than when they have a scar almost 10 times as large. Also, the risk of infection or complications decreases as the incision size does. The patient mentioned earlier with the Closed Heart Bypass surgery is a terrific example. After his surgery, he was cleared by his surgeon Dr. Mauro Rinaldi and released from the hospital after only 12 hours of recovery. The next week he was actually able to join his family on a vacation. In today's operating rooms, you'll find two or three surgeons, an anesthesiologist and several nurses, all needed for even the simplest of surgeries. Most surgeries require nearly a dozen people in the room. As with all automation, surgical robots will eventually eliminate the need for some personnel. Taking a glimpse into the future, surgery may require only one surgeon, an anesthesiologist and one or two nurses. In this nearly empty operating room, the doctor sits at a computer console, either in or outside the operating room, using the surgical robot to accomplish what it once took a crowd of people to perform.

The use of a computer console to perform operations from a distance opens up the idea of
telesurgery, which would involve a doctor performing delicate surgery miles away from the patient. The doctor doesn't have to stand over the patient to perform the surgery, and can control the robotic arms from a computer station just a few feet away from the patient. Having fewer personnel in the operating room and allowing doctors the ability to operate on a patient long-distance could lower the cost of health care in the long term. Besides the obvious rewards to the patient, Robotic Surgery is also very advantageous to the surgeon and hospital. In the ZEUS Surgical System, an “arm” on the machine is dedicated to the Automated Endoscopic System for Optimal Positioning (AESOP). AESOP is a 3D camera used in robotic surgery. It can be zoomed in by either voice activation or pedals located at the surgeon’s foot. Doctors who have used this actually argue that AESOP gives a better image than in real life. This is particularly true with surgeons that have poor vision or in microscopic surgeries that deal with nerves. Also, by using the hand controls the surgeons can reach places in the body that are normally unreachable by the human hand. Finally, the clearest advantage to using robots in surgery is in long operations, particularly ones that deal with nerve or tissue reconstruction. Surgeons often tire easily after performing microscopic surgery’s that last hours. However, by having the ability to be seated and have less strain on the eyes, doctors can control their natural flinching or nerves more efficiently

**Post-Surgery**

- Less scarring
- Faster recovery time
- Tiny incisions
- 0% Transfusion rate
- Shorter catheter time 5 vs. 14 days
- Immediate urinary control
- Significantly shorter return to normal activities (1-2 weeks)
- Equal Cancer Cure Rate
- Less post operative pain

**In-Surgery**

- Surgeons have enhanced view
- Easier to attach nerve endings
- Surgeons tire less easily
• Fewer doctors required in operating rooms
• In turn, cheaper for hospitals.
• Smaller risk of infection
• Less anesthesia required
• Less loss of blood

LIMITATIONS:

❖ The Question of Safety

In comparison to robots used in the industrial sector, medical robots present designers with much more complicated safety problems. Some of the most important factors which lead to such complexity are described below:

• Human presence: In an industrial situation, there are no humans present in the application environment. Should that be necessary, safety regulations specify that the robot be de-activated while humans are in the vicinity. This greatly simplifies the safety requirements and their satisfaction. In the medical sector, however, robots are required to assist rather than to replace humans. In that respect, they must be able to work in close proximity to humans and perform well in a chaotic, time-varying environment. This requires medical robots to have rich sensory and reasoning capabilities concerning their environment, something that both pushes the current technology to the limits and presents robot designers with insurmountable obstacles.

• Fault consequences: This is closely related not only to the presence of humans near the robot, but also to the nature of the task of the robot, which typically involves a human patient. In the industrial sector, a fault can mean at most some loss of physical equipment. In the medical sector, where lives are at stake, the implications are of profound importance.

• Non-generic task: In the industrial sector, the robot is required to perform a series of movements in some pre-defined order. The object it is operating on, be it as simple as a metal pipe or as complex as a car, is not distinguished in any way, that is, the robot is not required to take account of differences on an object-by-object basis, but treats them all as being equal. When dealing with patients, however, this is not possible. Each patient has their own distinguishing characteristics, making a uniform approach
inappropriate. In safety terms, this requires testing, or at least reasoning about infinitely many scenarios.

Possible reasons that can lead to unsafe operation of a medical unit include flawed design, malfunction of hardware and software components, misinterpretation and incorrect or inadequate specification. As in many other applications, improving some of these parameters results in a degraded performance in other areas, while an overall increased level of safety is accompanied by an increase in cost, complexity, or both. The idea of total safety is a fallacy. Instead, different safety strategies offer different advantages (and, or course, disadvantages). The overall probability of error must be always kept at very low levels. Perhaps even more important than the probability of a fault is the ability to detect that a fault has indeed occurred and prevent hazards resulting from it, that is, allow the robot to "fail safely". This usually involves shutting the robot down and removing it from the patient, and having the operation manually completed by a surgeon.

As the task which the robot undertakes becomes more and more complicated, there is an increasing need for more complex hardware and software components (faster response, better accuracy, more degrees of freedom). This increases the probability of error exponentially. Software is notoriously difficult to reason about, while hardware reliability never ceases to be of prime importance. A final consideration concerning safety is, perhaps surprisingly, size. Both patients and doctors feel uncomfortable working next to medical robots which tower above the surgeon at over 7 feet and weigh in at several tens of kilograms. There is some logic behind that, however. A larger robot can usually exert more force than a smaller one, resulting in an increased amount of damage in case of a fault.

- The Cost

The Robots that perform the surgeries cost around $750,000 to over $1 million. This is because they use extremely sensitive and experimental equipment that costs a lot of money. In addition to the cost of the machines the training that is needed for surgeons to learn how to use the systems is also very expensive. Because of the extreme cost of the machines at this point in time the procedures are slightly more expensive than a regular operation, but it does have its advantages. Many people in the medical field however believe that these surgeries will soon become more common and less expensive
THE FUTURE:

Robotic surgery is in its infancy. Many obstacles and disadvantages will be resolved in time and no doubt many other questions will arise. Many questions have yet to be asked; questions such as malpractice liability, credentialing, training requirements, and interstate licensing for tele-surgeons, to name just a few. Many of current advantages in robotic assisted surgery ensure its continued development and expansion. For example, the sophistication of the controls and the multiple degrees of freedom afforded by the Zeus and da Vinci systems allow increased mobility and no tremor without comprising the visual field to make micro anastomosis possible. Many have made the observation that robotic systems are information systems and as such they have the ability to interface and integrate many of the technologies being developed for and currently used in the operating room. One exciting possibility is expanding the use of preoperative (computed tomography or magnetic resonance) and intraoperative video image fusion to better guide the surgeon in dissection and identifying pathology. These data may also be used to rehearse complex procedures before they are undertaken. The nature of robotic systems also makes the possibility of long-distance intraoperative consultation or guidance possible and it may provide new opportunities for teaching and assessment of new surgeons through mentoring and simulation. Computer Motion, the makers of the Zeus robotic surgical system, is already marketing a device called SOCRATES that allows surgeons at remote sites to connect to an operating room and share video and audio, to use a “telestrator” to highlight anatomy, and to control the AESOP endoscopic camera.

Technically, many remains to be done before robotic surgery’s full potential can be realized. Although these systems have greatly improved dexterity, they have yet to develop the full potential in instrumentation or to incorporate the full range of sensory input. More standard mechanical tools and more energy directed tools need to be developed. Some authors also believe that robotic surgery can be extended into the realm of advanced diagnostic testing with the development and use of ultrasonography, near infrared, and confocal microscopy equipment.

Much like the robots in popular culture, the future of robotics in surgery is limited only by imagination. Many future “advancements” are already being researched. Some laboratories, including the authors’ laboratory, are currently working on systems to relay touch sensation from robotic instruments back to the surgeon. Other laboratories are working on improving current methods and developing new devices for suture-less anastomoses. When most people think about
robotics, they think about automation. The possibility of automating some tasks is both exciting and controversial. Future systems might include the ability for a surgeon to program the surgery and merely supervise as the robot performs most of the tasks. The possibilities for improvement and advancement are only limited by imagination and cost.

**CONCLUSION:**

Although still in its infancy, robotic surgery has already proven itself to be of great value, particularly in areas inaccessible to conventional laparoscopic procedures. It remains to be seen, however, if robotic systems will replace conventional laparoscopic instruments in less technically demanding procedures. In any case, robotic technology is set to revolutionize surgery by improving and expanding laparoscopic procedures, advancing surgical technology, and bringing surgery into the digital age. Furthermore, it has the potential to expand surgical treatment modalities beyond the limits of human ability. Whether or not the benefit of its usage overcomes the cost to implement it remains to be seen and much remains to be worked out. Although feasibility has largely been shown, more prospective randomized trials evaluating efficacy and safety must be undertaken. Further research must evaluate cost effectiveness or a true benefit over conventional therapy for robotic surgery to take full root.
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