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Latest Techniques and Models Used in Robotic Technology in the Field of 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 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

Keywords: Robots, surgery field, closed-chest, beating-heart surgery, Robotic Surgery, dexterity-enhancing.

I. Introduction

Robotics technology in surgery combines advanced computer engineering, 3D imaging, and artificial intelligence to enhance minimally invasive procedures. Systems like the da Vinci Surgical System enable surgeons to operate through tiny incisions with extreme precision, tremor filtration, and greater dexterity. Robotics technology in surgery enables doctors to perform complex procedures with unparalleled precision, flexibility, and control compared to traditional methods. While the robot assists with maneuverability and tremor reduction, it is entirely controlled by the surgeon at all times. Robotic surgery is an evolution of minimally invasive surgery that uses specialized robotic platforms to enhance a surgeon's precision, flexibility, and control. By acting as an extension of the surgeon's eyes and hands, it allows for complex procedures to be performed through tiny incisions. Robotic surgery (RS) is an evolution of minimally invasive surgery that combines medical science, robotics, and engineering. Also known as robot-assisted surgery, it is a sophisticated technique that involves the use of specialized robotic platforms during surgical procedures to improve the precision of surgeons' movements in complex procedures and small anatomical spaces. RS allows for the filtering of hand tremors, thereby improving flexibility and minimizing involuntary inaccuracies. As a result, it leads to fewer surgical complications such as surgical site infection, less pain, less blood loss, shorter hospital stay, quicker recovery, and smaller, less noticeable scars.

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Fig. no.1: Robotics technology

History

The history of surgical robotics evolved from early military tele-surgery concepts in the 1980s to the highly precise, AI-assisted, and minimally invasive systems utilized globally today. It transformed operating rooms by allowing surgeons to operate with enhanced precision, dexterity, and 3D visualization.

1920S

Robotic surgery was still a long way off but the concept of modern robotics began developing in the early 1900s. In 1920, Czech writer Karel Capek published a play called "R.U.R." which stands for Rossumovi Univerzaini Roboti or translated into English, "Rossum's Universal Robots."

This was the first instance of the word "robot" being used in the English language. Capek actually credited the invention of the word "robot" to his brother Karel Capek. They used the Czech word "robota" which means "forced labor," because, in the play, the robots become a serving class in society. And eventually, they rebel against humans, and that leads to the end of humanity.

1930-1969

During these next few decades, robots were still just a concept but were probably being worked on frequently. Science fiction authors also kept playing with the idea of super-advanced and intelligent robots and how they would interact with humanity. In Frank Herbert's Dune saga, robots played a role in the near extinction of humanity. In October 1966, the BBC broadcasted a series of episodes of the sci-fi series Doctor Who featuring robotic creatures known as Cybermen.

1970S

During this time period, NASA experimented with the idea of telesurgery, or remote surgery as potential support for astronauts while aboard the space station.

Similarly, the United States Defense Research Advanced Projects Agency researched telesurgery for long-distance battlefield surgery. Some advances were made, but full progress was not achieved until the 2000s.

1980S

The first records of robotic surgery performed date to the 80s. Specifically, the first surgical robot, PUMA 560, was used in a brain biopsy procedure. This procedure took place in 1985 as robotics started to be implemented to reduce movement due to hand tremors.

Then in 1988, the PROBOT, developed at the Imperial College London, was used to make several repetitive incisions during a transurethral prostate surgery.

1990S

At the beginning of the 90s, Integrated Surgical Solutions, Inc. and IBM developed ROBODOC. In

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1992, they successfully used ROBODOC to prepare the femur for hip replacement in human subjects.

By the late 90s, engineers had developed three different systems that combined laparoscopic technology with surgical robots. These systems were the da Vinci Surgical System, the AESOP, and the Zeus surgical systems.

2000S

2001 marked the Lindinburg Surgery, which was a major success for telesurgery. Doctors Jacques Marescaux, from France, and Michel Gagner, from Canada, performed a remote gallbladder removal surgery from New York City. The patient was in Strasbourg, France, during the procedure.

From the 90s and into the early 2000s, the Zeus system was used in several unique, or novel, surgeries. Some of the surgeries that were performed using the Zeus system include:

2010S

The da Vinci Surgical System has become the most prevalent robotic surgery device in the field. One of the most notable milestones occurred in August 2010 when Edward Hospital used the da Vinci Surgical System to peel the skin off of a grape.

The da Vinci system has been approved by the FDA for use in both adult and pediatric robotic surgery procedures in the following areas:

I. Urological surgeries;
II. General laparoscopic surgeries;
III. General non-cardiovascular thoracoscopic surgeries;
IV. Thoracoscopically-assisted cardiotomy procedures.

II. ROBOTIC SURGEONS

Robotic surgeons" usually refers to surgeons who perform operations using robotic-assisted surgical systems. The robot does not operate independently; the surgeon controls the instruments from a console, and the system translates the surgeon's hand movements into very precise movements inside the patient's body. a minimally invasive technique where a human surgeon operates specialized robotic systems, like the *da Vinci* system, from a nearby computer console.A robotic surgeon is not a robot that operates on patients by itself. It is a highly trained surgeon who uses a robotic surgical system to perform procedures with greater precision, flexibility, and control. The surgeon sits at a computer console, viewing a 3D image and controlling the arms with superhuman precision.

Common robotic surgery platforms include:

- da Vinci Surgical System — widely used for urology, gynecology, general surgery, and other procedures.
- Versius
- HugoRAS System

CLASSIFICATIONS

Classification of robotics surgery

Robotic surgery (robot-assisted surgery) can be classified in several ways:

Based on the Level of Robot Control

There are three types of classification…..

I. Supervisory- controlled robotic surgery system
II. Telesurgical (Master–Slave) Systems
III. Shared-Controlled Robotic Surgery System

Supervisory- controlled robotic surgery system

The surgeon performs extensive preoperative planning.

The robot executes the planned procedure under supervision.

Used mainly in highly precise tasks such as certain orthopedic procedures.

Supervisory-controlled robotic surgery systems are highly automated platforms where surgeons pre-plan procedures on 3D virtual maps. The robot autonomously executes specific, pre-programmed subtasks under the active supervision of the operating surgeon, ensuring extreme precision while maintaining an essential human safety net.

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Fig 2 : Demonstration

Telesurgical (Master–Slave) Systems

The surgeon directly controls robotic arms from a console.

The robot does not make independent decisions.

Most common type in clinical practice.

Telesurgical (master-slave) systems allow surgeons to operate remotely using robotic arms. The surgeon sits at a "master" console, viewing 3D imaging and manipulating hand controls, while a "slave" cart at the patient's bedside precisely replicates these movements inside the body

THE DA VINCI SURGICAL SYSTEM:

The **da Vinci Surgical System** is a robotic surgical platform that uses a minimally invasive surgical approach and is manufactured by Intuitive Surgical. The system is used for surgicals procedures including prostatectomies, cardiac valve repair and renal and gynecologic interventions. In 2012, it was used in an estimated 200,000 surgeries, most commonly for hysterectomies and prostate removals. The system is called "da Vinci" in part because of Leonardo da Vinci's study of human anatomy eventually led to the design of the first known robot in history. The da Vinci System consists of a surgeon's console that is typically in the same room as the patient, and a patient-side cart with three to four interactive robotic arms (depending on the model) controlled from the console. The arms hold objects, and can act as scalpels, scissors, electrocautery devices, or graspers. The final arm controls the 3D cameras. The surgeon uses the controls of the console to maneuver the patient-side cart's robotic arms. The da Vinci system requires a surgical team to operate and ensure patient safety throughout procedures.

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Fig 3 : da vinci surgical system

ZEUS ROBOTICS SURGICAL SYSTEM:

The **ZEUS Robotic Surgical System** (ZRSS) was a medical robot designed to assist in surgery, originally produced by the American robotics company Computer Motion. Its predecessor, AESOP, was cleared by the Food and Drug Administration in 1994 to assist surgeons in minimally invasive surgery. The ZRSS itself was cleared by the FDA seven years later, in 2001. ZEUS had three robotic arms, which were remotely controlled by the surgeon. The first arm, AESOP (Automated Endoscopic System for Optimal Positioning), was a voice-activated endoscope, allowing the surgeon to see inside the patient's body. The other two robotic arms mimicked the surgeon's movements to make precise incisions and extractions. ZEUS was discontinued in 2003, following the merger of Computer Motion with its rival Intuitive Surgical; the merged company instead developed the Da Vinci Surgical System.

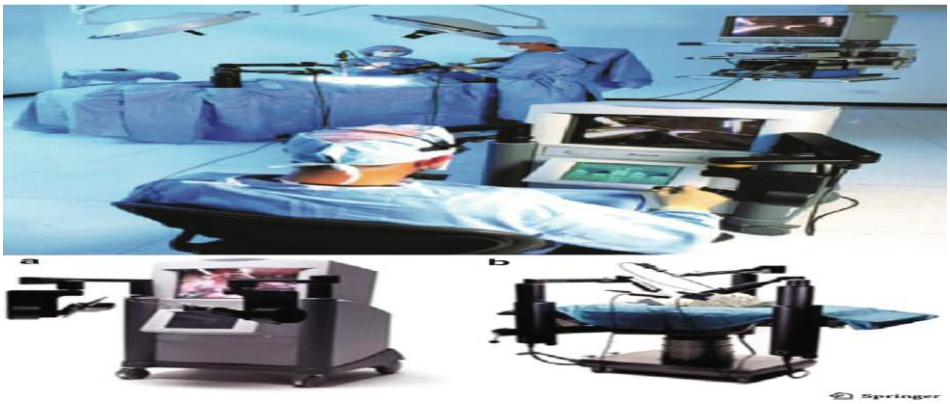

Fig 4 :ZUES SURGICAL SYSTEM

The ZEUS Surgical System features the following component:

- Video console
- Support Video monitor up 23”D
- Flat Panel Monitor: with support for an addition 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 an HERMEST™ control center; mounting shelves for housing Control Units

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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 SOCRATESTM

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 rammingsomething
- Wrist

1 Fixed change in angle

- Elbow Tilt (+/- 3 degrees)

Scaling

Offers infinite motion scaling, without limitation to arbitrarily defined increments. Scaling adjustment

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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.

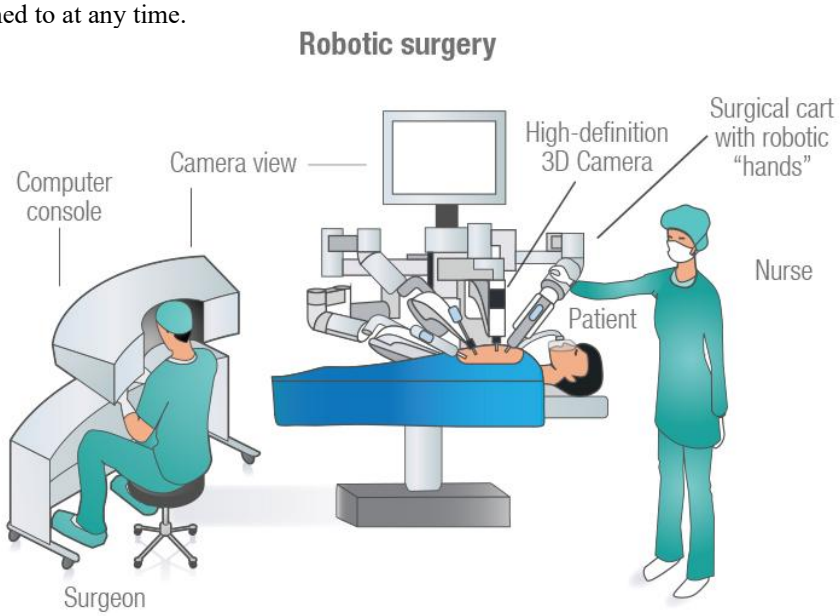
Re-Indexing: At any time, the foot pedal releases the clutch, allowing surgeons to relax and reposition (center and re-index) their hands and arms.

Endiscopic 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.

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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-Controlled Robotic Surgery System

Surgeon and robot work together.

The robot assists by improving precision, stability, or restricting unsafe movements.

Common in orthopedic and neurosurgical applications.

Shared control robotic surgery systems combine human intelligence with autonomous algorithms. Both the surgeon and the robotic system operate simultaneously toward a shared surgical goal. The robot enhances the surgeon's precision, cancels out hand tremors, and enforces safety boundaries, while the human retains executive control and makes complex decisions.

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 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.

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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.

(a) (b)

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

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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 arthoplasty: 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 Detroitperformed 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 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 toget 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 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.

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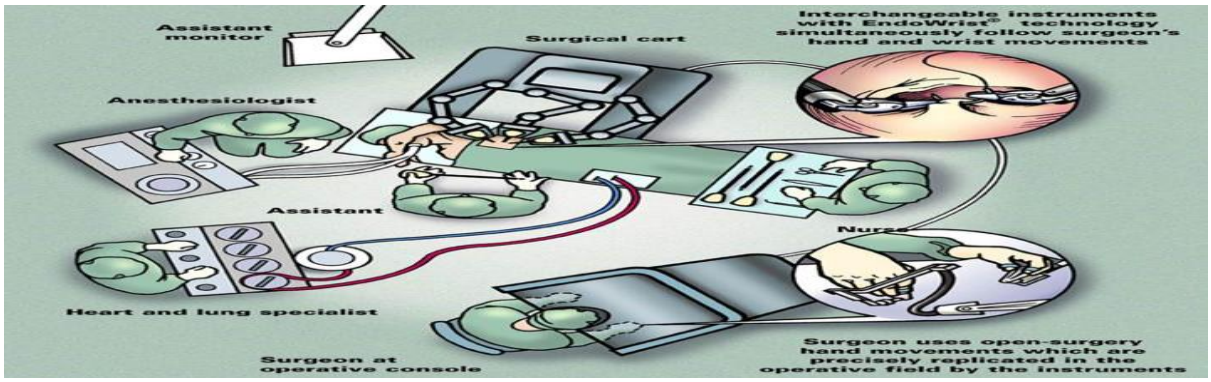

The use of a computer console to perform operations from a distance opens up the idea of telesurgery, which would involve a doctor performing delicate surgery miles away from the patient. The doctor doesn't have to stand over the patient to perform the surgery, and can control the robotic arms from a 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 surgeons 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 afterperforming 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

1. Less scarring
2. Faster recovery time
3. Tiny incisions
4. 0% Transfusion rate
5. Shorter catheter time 5 vs. 14 days
6. Immediate urinary control
7. Significantly shorter return to normal activities (1-2 weeks)
8. Equal Cancer Cure Rate
9. Less post operative pain

In-Surgery

a) Surgeons have enhanced view
b) Easier to attach nerve endings
c) Surgeons tire less easily
d) Fewer doctors required in operating rooms
e) In turn, cheaper for hospitals.
f) Smaller risk of infection
g) Less anesthesia required
h) Less loss of blood

III. LIMITATIONS:

Robotic surgery, while highly advanced and beneficial in many minimally invasive procedures, still has several limitations that restrict its universal use in healthcare.

One of the major limitations is the extremely high cost of robotic surgical systems such as the da Vinci Surgical System. The initial installation cost, maintenance, and disposable instruments make robotic surgery significantly more expensive than conventional laparoscopic or open surgery, limiting its availability in many hospitals, especially in developing countries.

Robotic surgery is not widely available in all healthcare centers. It is mostly confined to large, well-funded hospitals and urban medical institutions. Patients in rural or underdeveloped regions often do not have access to such advanced surgical options.

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Surgeons performing robotic surgery do not receive direct “touch” or tactile feedback. This lack of haptic sensation can make it difficult to judge tissue resistance, which may affect precision in certain delicate procedures.

Robotic surgery requires specialized training and significant experience. Surgeons must undergo extensive training to operate robotic systems effectively. The learning curve can initially increase operative time and reduce efficiency.

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 shuttingthe 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

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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

IV. FUTURE PROSPECTUS:

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.

V. 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, andbringing 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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