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# A Review on General Robotic Surgical Systems in Modern Sciences

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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.**

***Keywords*: Da vinci surgical system, Zeus surgical systems, Aesop surgical system.**

## 1. 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 I the 21st century. We've already seen how robots have changed the manufacturing of the 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 able to visit, in coming decades we may see the robots have artificial intelligence example: Honda's AISMO robot-which resembles human form. Doctors around the world are using sophisticated robots to perform surgical procedures on patients. [3][7] While robotic surgery systems are uncommon, several hospitals around the world bought robotic surgical systems. These systems have the potential to improve the safety and effectiveness of surgeries. But these systems also have some drawbacks. It's still a relatively young science and it's very expensive. Some hospitals may holding back on adopting the technology [1]. 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 unnamed surgery [9].

## 2. Robotic system

The first generation of surgical robots are readily being installed in a number of operating rooms around the world. These are not true autonomous robots that can perform surgical tasks on their own, but they are lending a mechanical helping hand to surgeons [13], [5]. These machines still require a human surgeon to operate them and input instructions. Remote control voice activation are the methods by which these surgical robots are controlled. Robotics are introduced into 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 on endoscope, perform gallbladder surgery and correct gastro-oesophagal 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 [4], [15].

According to the one manufacturer, robotic devices could be used in more than 3.5 million medical procedures in United states alone.

## 3. Classification

Not all surgical robots are equal. There are three different surgical systems:

- Supervisory controlled systems
- Shared-control systems
- Telesurgical systems

The main difference between each systems is how involved a human surgeon must be when performing a surgical procedure. On one end of spectrum, robots perform surgical techniques without the direct intervention of a surgeon. On the other end, doctors perform surgery with the assistance of robot, but the doctor doing most of the work.[2][6]

## 4. Supervisory- controlled robotic surgery systems

Of the three kinds of robotic surgery, supervisory-controlled

systems are the most automated. But 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 robots can operate. 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 is no room for errors –these robots can't make adjustments in real time if something goes wrong. Surgeons must watch over the robots action and be ready to intervene if something's gone wrong. [7][10].

Fig. 1.

In the planning stage, surgeons must take images of the patient's body to determine the surgical approach. Common imagining methods include CT scans, MRI scans, ultrasonography, fluoroscopy, and X-ray scans. The surgeon must have imaged the patient, the surgeons must tell the robot what the proper surgical pathway is. The robot can't make these decisions on their 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 of the patient's body that correspond the images created during the planning phase. The surgeon must watch the points exactly in order for the robot to complete the surgery without error.[2] The final phase is navigation. This involves the actual surgery. The surgeon must first portion the robot and the patient so that every moment the robot makes corresponds with the information in its programmed path. Once everyone is ready the surgeon activates the robot, which carries out instructions.[2][15]

## 5. Shared-control surgical systems

Shared-control surgical 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 supports through active constraint. [9][3]. Active constraint is a concept that relies on defining region 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 must be a specific site on the patient's hip. Safe regions do not border soft tissues.

While surgical robots offers some advantages over the human hand , we are still a long way from the day when autonomous robots will operate on people without human interactions, but with advance in computer power and artificial intelligence, it could be that in the century scientists will design a robot that can locate abnormalities in the human body analyze them and operate to correct those abnormalities without any human guidance.[19]

### *A. Telesurgical systems: The da vinci surgical system*

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. 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.[11][14]

Fig. 2. Types of instruments used by the da Vinci Surgical System

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 electro artery 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.[10][3][8] 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 (Fig 3.2.1.1). 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.[5][16]

The da Vinci System is FDA cleared for a variety of surgical procedures. These procedures include:

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

Surgeons are beginning to employ the da Vinci System to remove tumours 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. [21]

Fig. 3. Da vinci surgical system

*B. 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. [9][5]

**6. Zeus 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 microsurgical tasks.


Fig. 4. Zeus surgical system

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 monitor

Fig. 5. Components

Surgeon Control Console

- Touch Screen Monitor
- Support Arms and Surgeon Handles
- Mounting Areas: for speakers;
- Access to controller front panels;
- Access to PC and HERME Control centre
- 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 Re-usability
- 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 Scanlon, Storz and US Surgical. Quick Instrument Changes .[3][5][8][16].

### *A. 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.[18]

### *B. 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. [12]

### *C. Advantages*

Advantages for surgeons using robotic surgery include:
- Greater visualization
- Enhanced dexterity
- Greater precision

Robotic surgery is an advanced form of minimally invasive or laparoscopic (small incision) surgery where surgeons use a computer-controlled robot to assist them in certain surgical procedures. The robot's "hands" have a high degree of dexterity, allowing surgeons the ability to operate in very tight spaces in the body that would otherwise only be accessible through open (long incision) surgery.[17] Compared to open surgery (traditional surgery with incisions), robotic and minimally invasive surgery results in smaller incisions resulting in less pain and scarring.

Robotic surgery allows surgeons to perform complex surgical tasks through tiny incisions using robotic technology. Surgical robots are self-powered, computer-controlled devices that can be programmed to aid in the positioning and manipulation of surgical instruments. This provides surgeons with better accuracy, flexibility and control. [12]

When performing robotic surgery using the da Vinci Surgical System:
- The surgeon works from a computer console in the operating room, controlling miniaturized instruments mounted on three robotic arms to make tiny incisions in the patient.
- The surgeon looks through a 3-D camera attached to a fourth robotic arm, which magnifies the surgical site.
- The surgeon's hand, wrist and finger movements are transmitted through the computer console to the instruments attached to the robot's arms. The mimicked movements have the same range of motion as the surgeon allowing maximum control.
- The surgical team supervises the robot at the patient's bed. [12][17]

### *D. Disadvantages*

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: [11]
- 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. [23] This requires medical robots to have rich sensory and reasoning capabilities concerning their environment, something that both
- 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. Pushes the current technology to the limits and presents robot designers with insurmountable obstacles. [26][16]
- 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. [24]

*E. 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 many people in the medical field however believe that these surgeries will soon become more common and less expensive.[8]

*F. The applications*

Medicine is going through technological revolution that produces a paradigm shift and makes us in think in new ways of treating and diagnosing our patients. Minimally invasive surgery development and routine application in multiple procedures has been the main evolution in the last 50 years, bringing great benefits to patients, surgeons, hospitals and even insurance companies.

In laparoscopic surgery the surgeon keeps controlling by handling patient's tissues inside an insufficiated cavity with an external fulcrum point for instrumentation. [17][25] It changes drastically in robotic surgery, with the surgeon taking place in a virtual environment outside the operative field, with a distant and indirect control. SAGES defines robotic surgery as a surgical procedure but adds a computer technology enhancement interface to the interaction between the surgeon and his patient during a surgical operation and assumes some degree of controlled heterofore completely reserved for the surgeon.[25]

Surgical robots have been envisioned to overcome the limitations and extend the capabilities of human surgeons, allowing them to perform price and reproducible tasks. Its performance is looted in the strength and weakness of laparoscopic surgery, being able to avoid the fulcrum effect, overcome the limited range of moments and depth prescription, and dismiss the surgeon physiological tremor, while keeping its minimally invasive nature.

Robotic surgery or computer assisted surgeries and intra active system fast and initiative that allows the computer to disappear from the surgeons mind, who sends as real the environment generated by the system. Through virtual reality, the surgeon defines the manoeuvers that the robots performs in the patients. The console manipulator device can be placed in the same operating room, or in a different place, or eventually in another city or country.[27]

The robotic surgery shows various advancements in different research fields some of them are as follows:

- *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. [2]
- *Gastrointestinal surgery*: Multiple types of procedures have been performed with either the Zeus or da Vinci robot systems, including bariatric surgery. [24]
- *Gynaecology:* Robotic surgery in gynaecology is one of the fastest growing fields of robotic surgery. This includes the use of the da Vinci surgical system in benign gynaecology and gynaecologic oncology. [22][4] Robotic surgery can be used to treat fibroids, abnormal periods, endometriosis, ovarian tumours, pelvic prolapse, and female cancers. Using the robotic system, gynaecologists 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. [25]
- *Neurosurgery:* Several systems for stereotactic intervention are currently on the market. MD Robotics 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. [23]
- *Paediatrics:* Surgical robotics used in procedures including: trachea oesophageal fistula repair, cholecystectomy, nissen fundoplication, morgana hernia repair, kasai Porto enterostomy, congenital diaphragmatic hernia repair, and others.[20][2] 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.[7]
- *Radio surgery:* The Cyber Knife Robotic Radiosurgery System uses image-guidance and computer controlled robotics to treat tumours throughout the body from virtually any direction. [15]
- *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. [3][24]

## 7. 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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