Robotic Surgery

Technology in Medicine

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HISTORY of ROBOTIC SURGERY

Robotic surgery first surfaced in 1985 in London, England at the Imperial College of Science, Technology, and Medicine. Imperial College London is a prominent school that presently rates fifth overall by QS World University Rankings. The institution specializes in science, engineering, medicine, and business so it is not surprising that ground-breaking technology would emerge at such an exquisite school as Imperial College. The first surgical robot is known as the PUMA 56. The PUMA 56 was created to place a needle for a brain biopsy using CT guidance, which was successful because brain biopsies are extremely precise and can cause life altering damage to the patient if they are not executed properly. The PUMA 56 reduced procedure risk and proved itself for further research and investments into surgical technology. Three years later, in 1988, the PROBOT was developed to perform prosthetic surgery. Prosthetic surgery made the transformation from drawing blood samples and the simplicity of a needle to actual surgery and replacing one’s limbs and other missing body parts. However it was still another four years later until the third surgical robot came about; ROBDOC. The ROBDOC from Integrated Surgical Systems was built to grind out precise fittings in the femur for hip replacement, which was a more invasive and complicated procedure.

During the late 1980s research at Stanford Research Institute caught the attention of National Institute of Health. By 1990, Stanford was receiving funding to develop a prototype robotic surgical system. The study caught the
attention of the Defense Advanced Research Projects Administration (DARPA). DARPA wanted a system that potentially allowed surgeons to operate remotely on soldiers wounded on the battlefield. They immediately began pulling funds in order to research and implement new and potential opportunities.

In 1995, the intellectual property of the prototype was sold by Stanford and was incorporated into a new company named Intuitive Surgical Devices, Inc. Two years later, Intuitive Surgical introduced a prototype for testing. The first prototype was named Lenny after the late Leonardo da Vinci. Through trial experimentation the original system was refined and the design went through many modifications. The final version of the prototype was named the da Vinci. The da Vinci Surgical System was initially marketed to Europe in 1999, while it was awaiting Food Drug Administration approval in the United States.

The da Vinci Surgical System encompasses three apparatuses: a surgeon’s console, a patient-side robotic cart with four arms manipulated by the surgeon (3 instruments to maneuver and one camera control), and a 3-D vision system. The camera offers an actual stereoscopic picture transmitted to the surgeon’s console. To eliminate hand tremor the surgeon’s hand movements are scaled and filtered before being translated into micro-movements of the proprietary instruments. The surgical instruments are inserted through small plastic tubes (often used to administer oxygen and fluids).

In May 1998, the first robotic surgery (a heart bypass) took place in Germany. Interestingly, the world's first surgical robotics beating heart coronary
artery bypass graft was performed in Canada by Dr. Douglas Boyd and Dr. Reiza Rayman using the ZEUS surgical robot (ZEUS was the physical machine paired with the da Vinci before the systems were incorporated).

Once the FDA approved use of the da Vinci Surgical System the number of hospitals throughout the Americas and Europe using the system totaled eight hundred. The technology began to spread and grasp hold of everyone in its sight. The first robotically assisted surgery in the United States took place at Miami Valley Hospital in Dayton, Ohio by Dr. Randall Wolf and Dr. Robert Michler. Captivatingly enough, by 2001 a doctor in New York preformed a complex procedure on a woman in France.

By 2006 some forty-eight thousand procedures are available using the da Vinci. Common procedures include surgery for prostate cancer, hysterectomy, and mitral valve repair. Presently the da Vinci costs $1.2 million base cost, minus any maintenance costs and training expenses. Just this past April, Intuitive Surgical introduced the surgical system with high definition quality images for $1.75 million.

In mid 2006, the first Artificial Intelligence doctor (nonhuman) conducted unassisted surgery of the heart. Shockingly, the results of the surgery were better than those preformed by human surgeons. The mechanical human is capable of performing some 10,000 operations. By 2009, a team of surgeons in New Jersey supervised eight fully robotic-unassisted organ transplants in a six
month period. The creators of the autonomous robotic system believe that within 15 years these robotic surgeons will replace half of all human surgeons.

Robotic Surgery first surfaced some fifteen years ago. Since then the advances in Robotic surgical technology has exploded. The industry is primarily dominated by the da Vinci surgical system as a result of its versatility. Nonetheless, self-sufficient systems like the Artificial Intelligence surgeon will likely dominate the surgical industry in the future.

**APPLICATIONS**

**CARDIOLOGY**

There are many kinds of different technologies and applications used in robotic surgery. These technologies vary based on the particular individual’s situation, like how irate the surgery is expected to be. The applications very on what specific procedure has to be performed.

**Stereotaxis Magnetic Navigation System (MNS)**

The MNS (Magnetic Navigation System) is a robotic system, which was designed to help physicians to perform precision and safety in specific procedures such as arrhythmias and atrial fibrillation. The illness of an atrial fibrillation is when the heart does not have consistent heart rhythm. The main purpose of the MNS is for more complicated cardiology interventional procedures. It navigates magnetically directed tools inside the body by controlling a magnetic field. The devices’ precise motions are control by
computerized magnetic fields. The MNS helps navigate catheters, guide wires, and other devices into the blood vessels and the chamber from the heart. This is to enter into the site that needs to be treated, which are likely small and narrow regions.

**How It Works**

The robotic system uses two magnets attached on the pivoting arms that are connected within a stationary housing. One magnet is on a side of the patient table and the other is inside the catheterization lab. These magnets create magnetic navigation fields which are less than ten percent of the strength of fields that are produce by regular MRI equipment. The disadvantages of common MRI equipment provide less protection from a magnetic field and more interference compare to the MNS.

One important advantage of the system is that it creates automated three dimension mapping of the heart and vasculature. The MNS can automatically examine the whole heart chamber with pressing only one button, whereas if a regular surgeon were to do any kinds of imaging of the heart it could take hours in comparison.

The automated mapping software facilitates physicians in treating difficult arrhythmias such atrial fibrillation and atrial flutter. The reason being is that it produces a map of about one hundred and twenty contact points of each chamber of the heart. The software takes a maximum ten minutes, which is considered very quick and a very precise measurement. It reduces time and
skill-intensive manual mapping procedures and therefore the physician can focus more on the treatment.

**Equipment**

The Magnetic Navigation System comes with remote instrument control of a “point and click” or joystick-operated technology, which can be control either from the patient table or from a room next to the patient, but it has to be outside the x-ray fluoroscopy field, otherwise the x-ray field could possibly become distorted. This system uses the following devices; Magnetic GentleTouch catheters, magnetic coronary guidewires, and the CardioDriveCatheter Advancement System. The magnetic catheters used with the system can apply a lightly controllable contact pressure, or force at the working tip. The CardioDrive automated catheter advancer is used to move forward and pull in a catheter in the patient's heart while the magnets precisely move the working catheter tip. It helps the physician and his or her staff to perform an electrophysiology procedure from the control room.

**NEUROLOGY**

**NeuroArm**

Several systems for stereotactic intervention are currently on the market. The first robotic surgeon in the neurology field is the neuroArm and is the world’s first MRI-compatible surgical robot, which can perform both microsurgery and
stereotaxy. The project began in 2001 with an initial investment of $2 million. It was developed by Dr. Garnette Sutherland, Professor of Neurosurgery in the University of Calgary Faculty Medicine. It was officially launched on April 17, 2007. NeuroArm was designed to replace the main neurosurgeon. The project cost about $27 million to implement.

How It Works

The neuroArm is controlled by the surgeon from a computer console that uses controllers and magnetic resonance imaging (MRI). The robot can use multiple tools and can still be more precise and accurate than a surgeon. In addition, the tools can be manipulated at a microscopic scale. In using the neuroArm, the surgeon can place in a MRI scanner and use the remote devices to operate. It creates a live MRI picture in order to know what is going inside. It provides in depth information of where to cut and make adjustment on the procedures. The robot is considered “accurate to less than half the width of a human hair, more than 20 times the dexterity of a human hand” (Sutherland).

One advantage of the neuroArm is that its motor is all ceramic, which it doesn’t distort the MRI’s magnetic field. The motor is considered non-magnetic; therefore, it is compatible with the MRI equipment. The robot contains two special hand controller moved by the surgeon's hands. The robotic arms have a sense of touch which is an advantage of the robot. The hand controllers help the surgeon to control the left and right robotic arms. The arms help the surgeon differentiate a bone from a soft tissue. The reason that this robot is
capable of having such a sense of touch is because of the robot status touch screen located at the control center. It is also to note that the surgeon can set the calibration. An example is that if the hand controller displaces a 1 cm it creates a 1 mm movement of the surgical tool. This allows surgeons to perform delicate procedures.

**Equipment**

The system includes a workstation, a system control cabinet, and two remote manipulators attached onto a mobile base. It also has MR compatible manipulators with end-effectors which bounds with microsurgical tools. The neuroArm has filters to get rid of unnecessary tremors. Also, the end-effectors have three-dimensional force-sensor, which provide sense of touch. The surgeon has the option to seat at the workstation or stand up. He or she is able to control the neuroArm by using force feedback hand controllers. The workstation demonstrates a display of the surgical site and three dimensional MRI images, with the tools. In addition, the telerobotic operations can be perform inside and outside the magnets by via specific tool sets using standard neurosurgical instruments such as adapted to the end effectors. Therefore, the neuroArm is capable of cutting and manipulating soft tissue, dissecting tissue planes, stitching, and biopsy.

**Da Vinci System**
How It Works

The robotic system is a combination of a traditional open surgery and conventional minimally invasive surgery. In a *da Vinci* Surgery, small incisions are performed to insert small instruments and a high-definition three dimensional camera. Therefore, the surgeon can view a magnified, high-resolution 3-D image of the surgical site. In using the system, the surgeon’s hand movements are translated into computerized and precise micro-movements of the system’s instruments. Therefore, the surgeon controls the movement of the system. In addition, the system movements are more precise than human hands. The *da Vinci* System is considered safe when the power fails. If there is a power interruption or a safety failure, the system can program itself to shut down safely, and the surgeon can still have control of the procedure. Overall, with the system a surgeon can perform major surgery with only a few tiny incisions. Also, the robotic system can operate with better visualization, precision, dexterity and control than using traditional surgical approaches.

The system has been used in a plethora of surgeries. On February 12, 2008, a surgeon performed minimally invasive coronary artery bypass surgery, also known as *da Vinci* coronary revascularization. During the procedure there were no complications and the patient was able to recover in two weeks. The *da Vinci* system reduces chance of infection, shortened hospital stay, and improves recovery time. The *da Vinci* has been used in many cardiologic surgeries for quite a while. New studies and experiments have continued to build on the previous triumphs of the *da Vinci* procedures.
The *da Vinci* cost millions to hospitals and the surgery is more than $15,000. It is available in 47 states and is not for everyone. Patients who are overweight and have had previous operations are not candidates for this type of surgery. Robotic Surgery is still a generally new concept and thus doctors and other investors are trying to boost their success rates by minimizing potentially risky operations, so that the success rates are higher.

**Equipment**

The system has three components: the surgeon console, the patient cart and four robotic arms. It contains a three dimensional high definition camera. It mimics many of the same characteristics and qualifications as the other forms of robotic medicinal technology. However, the *da Vinci* system carries four arms and the implements are all interchangeable, which means the implements can be chosen based on the procedure being performed.

**ADVANTAGES**

Robots in the field of surgery have made significantly advances that changed surgery systems for the better. The biggest factors in the advantages in robotic surgery are the decrease in pain and scaring to the patient. The precision of incisions made by the robots are made possible by the used of enhanced visual effects and cameras, this gives the doctors full control to make the tinniest incisions. The *Zeus* system and *Da Vinci* system uses arms to operate. They make few centimeters of incision to operate and get inside the
body. A cardiac bypass surgery was performed in San Matteo Hospital in Pavia, Italy; the robot made three one-centimeter incisions, typically in this type of surgery, the incisions would have been about thirty centimeters in length.

Since the robots make these tinniest incisions the patients’ hospital stay is greatly reduced and the patients can recover a lot faster than normal surgery. A patient that gets a three centimeters scars have far less possibility of contracting an infection, complications than having a scar that is ten times as large. The patient mentioned above is a terrific example. According to Dr. Mauro Rinaldi, the patient was released from the hospital after twelve hours of recovery; he then joined his family on a vacation the following week. Robotic surgery does not only benefit the patient but it is also beneficial for 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 three dimensional camera used in robotic surgery. This system can be used for either voice activation or zooming option with the use of pedals that is located by the foot of a surgeon. Surgeons that have actually put this system to use have argued that this system gives a better picture than in real life. The use of “hand controls” allows the surgeons to reach places in the body that is usually inaccessible by the human hand. Lastly, the absolute advantage to the use of robots in surgery is in long operations. Surgeons frequently tire after a long microscopic surgery that often last for hours. However, with robotic surgery, the surgeons are seating down and have less strain on their eyes and have more
control over their nerves or natural flinching.

**DISADVANTAGES**

Unlike the robots in the industrial sector, medical robots are far more complicated and present designers with complex safety problems. Humans that are near the presence of robots are closely related to fault consequence. For the industrial portion, this could mean a loss of equipment or a slow down in production; but in the medical field there are lives that are at stake.

Some of the reasons that could possibly lead to an unsafe operation of the unit are software and hardware components malfunctioning, a flawed design, inadequate or incorrect specification. Improving some parts of these parameters results in degraded performance in some areas, while increasing the safety features usually comes with a hefty price. The thought of total safety is a misleading notion. Different safety strategies present different advantages and disadvantages. The overall chance of error should be always kept at extremely low levels.

As technology advances robotic surgery undertakes more and more complicated tasks. There will always be an increasing need for more complex software and hardware components to improve performance of the robot. This adds to the cost and maintenance.

The one thing robots lack is human intelligence. They are machines that are in risk of mechanical failure. In the middle of surgery, if hardware or software failure takes place, it can lead to fatal consequences. Robots are
unable to make logical decisions under difficult circumstances; they simply do what they are programmed to do. There are several situations in which a doctor has to make uncalculated evaluations based off of human feeling and what is right for that patient. Surgeons also have a hard time adapting to the concept of being behind the controls of a robot. They have experience and hours of practice of performing the real surgery, but controlling a robot can decrease their knowledge. If a surgeon is not comfortable directing a robot to do open heart surgery, caution may double the time it takes to actually perform the surgery.

Fear of the robot itself is also a disadvantage. Patients and doctors feel uncomfortable working next to a robot that towers over 7 feet and weighs in at several tons. It can be quite intimidating. Also, many patients who are not educated about technology may not be able to trust their lives to a machine. Patients may opt out of robotic surgery and request the doctor perform the surgery hands on.

WHERE WE ARE TODAY

Currently there are hundreds upon hundreds of new robotic technologies being researched and possibly implemented. There are two main robotic systems that have been developed which are the ARTEMIS system and a miniature robotic system. The ARTEMIS was developed by Schurr et al at Eberhard Karls University. This system consists of two robotic arms which are controlled by a surgeon at a control console. The miniature robotic system was developed by Dario et al at the MiTech Laboratory of Scuola Superiore Santa
Anna in Italy. The Miniature robotic system provides the same functions as conventional colonoscopy systems but it does so with an inchworm like locomotion using vacuum suction. The miniature robotic system does the job quite well because it allows the endoscopist to teleoperate (directly supervise this endoscope and with the functional integration of endoscopic tools). This system could expand the application of endoluminal diagnosis and surgery.

The Food and Drug Administration has approved two robotic systems for use with adults and children which are the Intuitive Surgical da Vinci Surgical System and the Zeus MicroWrist Surgical System. These systems are now used to perform most surgeries in children that can be performed laparoscopically and thoracoscopically, because they can enter the smaller vicinities as in children’s organs.

The da Vinci system evolved from the telopresence machines which were developed for NASA and the US Army. In this system are essentially 3 components:

1. A vision cart that holds a dual light source and dual three chips cameras.

2. A master console where the operating surgeon sits, moveable cart where two instrument arms and the camera arm are mounted; the camera arm contains dual cameras and the image generated is three dimensional

3. The console consists of an image processing computer that generates a true three dimensional image with depth of field; the view port where the
The surgeon views the image; foot pedals to control electrocautery, camera focus, instrument/camera arm clutches, and master control grips that drive the servant robotic arms at the patient’s side. The instruments are cable driven and provide seven degrees of freedom. This system displays its three dimensional image above the hands of the surgeon so that it gives the surgeon the illusion that the tips of the instruments are an extension of the control grips, thus giving the impression of being at the surgical site.

The Zeus system is composed of a surgeon control console and it has three table-mounted robotic arms. The right and left robotic arms replicate the arms of the surgeon, and the third arm is an AESOP voice-controlled robotic endoscope for visualization. The way to use the Zeus system is with the surgeon is seated upright with the video monitor and instrument handles positioned ergonomically to maximize dexterity because it allows complete visualization or the environment. The system uses both straight shafted endoscopic instruments similar to conventional endoscopic instruments and jointed instruments with articulating end-effectors and 7 degrees of freedom.

PREVALENT FUTURE OPPORTUNITIES

Robotic systems are information systems and combine many of the technologies being developed for and currently used in the operating room.
Massive amounts of information are related through technology and translated into actions. One possibility that the system can bring in the future is expanding the use of preoperative stage of patient treatment (computed tomography or magnetic resonance) and intraoperative video image fusion to better guide the surgeon in dissection and identifying the pathology. It could make the possibility of long-distance intraoperative discussion or guidance and it could provide new opportunities for teaching and assessment of new surgeons through mentoring and simulation.

A new device using the computer motion is called SOCRATES which allows surgeons at remote sites to connect to an operating room and share video and audio, to use a telostrator to highlight anatomy and to control the AESOP endoscopic camera.

Future systems might bring greater abilities for surgeons to program their surgeries and merely supervise as the robots perform most of the tasks. The possibilities are limited because of imagination and the cost associated with developing such technological contraptions.

Medical Schools across the world, utilize new and innovative methods of robotic surgery. Medical Schools, as with any form education, shape future industry trends. If robotics are being taught in schools, then when students graduate and begin practicing medicine they may very well be more inclined to provide the options for robotic surgery for patients. If you recall the original concepts of robotic surgery began in schools and spread to other organizations.
The popularity of robotic surgery can be predicted to expand as many students going through medical school can be expected to carry it on through their practice.

**CONCLUSION**

With the miraculous breakthroughs we have made in medicinal technology over the past three decades, it is no surprise that the future of robotic surgery gleams with optimism. Robotic surgery gives patients chances, opportunities and faith in medicine that would otherwise be unavailable. The ability for a doctor to tell a patient that the recovery for a procedure is up to six times faster allows a patient to feel instant relief and get back to their everyday lives sooner. That feeling is irreplaceable, and makes us strive for further advancements.
Works Cited


http://eu.stereotaxis.com/Hospital/Magnetic-Navigation/


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