Robots in the Field of Medicine
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1 Pioneers

The use of robots in medicine is where it is today because of four major companies. The original pioneer was Computer Motion[2], which was founded in 1989 with the goal of revolutionizing surgery using robots. The company produced the first robot approved by the FDA for the use of surgery and named it Aesop[2]. Today Aesop has been used in thousands of surgeries. The next major pioneer bringing robots to the forefront of surgery is Intuitive Surgical[2]. Intuitive Surgical developed the Da Vinci[3] using technology from Aesop. The Da Vinci was a major advance because it made the robotic surgery as easy to control as open surgery. Integrated Surgical Systems Inc.[4] brought the next major advance in robotic surgery with Robodoc[4]. Robodoc can cut patients remotely, which was a major advance in technology. The final major pioneer for the use of robotics in medicine is Accuray Incorporated[1]. Accuray Incorporated developed CyberKnife[1], which can treat lesions anywhere in the patient's body using radiation. This advancement Is crucial because it removed the risk of radiation harm to the doctor.

1.1 Aesop

Aesop is a robot, which holds an endoscopic camera for the doctor essentially creating a third arm. The robot allows for minimal invasion and faster recovery. Originally it was operated by foot pedals, which was a great invention because pedals eliminated tremors inevitable in even the best surgeons. In December of 1993 the FDA approved Aesop making it the first surgical visual aid robotic device approved by the FDA[1]. In 1996 a voice control was added to the system to make use easier for newer surgeons who had trouble looking down to use the pedals. Aesop was modified two more times adding another degree of freedom in the arm and more smart technologies.

Figure 1: Dr. Krongrad and an AESOP robot.

1.2 The Da Vinci

The Da Vinci Surgical System is a robots utilized in surgery, which unlike previous robots that used only one camera to provide a 2D image, uses two cameras mounted on one of its four arms to give the surgeon a 3D image which can greatly increase a surgery's success. Along with two cameras on one arm, the Da Vinci has three other arms which tools can be attached to. The Da Vinci is controlled by two foot pedals and arm controls that give the user better control. As the user moves these foot pedals and arm controls, the system scales down the movements to a micro level for minimally invasive surgery.

Figure 2: The Da Vinci Surgical System

1.3 Robodoc

Robodoc is used in knee and hip replacement. First Robodoc uses a combination of images and software create a surgical procedure. Before the surgery the surgeon defines the cavity in the hip bone and the size and position of the prosthesis. Robodoc runs the program and performs the surgery. The patient is cut without the direct control of the surgeon over the cutting tool. The result is a cleanly cut cavity and an accurate, precise fit. Through these methods Robodoc has quickened recovery time and hip replacements last much longer.

Figure 3: Robodoc

1.4 Cyber Knife

On October 1st 2001 Accuray Incorporated received clearance from the FDA for the use of their robot, CyberKnife, in surgery. The robot uses robotic arm equip with a lightweight linear accelerator that is used to deliver radiation to regions anywhere in the body. CyberKnife uses a Stereotactic Radiosurgery System, which uses the body's skeletal structure to create the future movements the robot will make, and Dynamic Tracking Software to compensate for small patient movements. Using CT images lesions are marked in their relation to the bone structure and real time X-ray the lightweight linear accelerator is positioned to accurately deliver the radiation beam.

Figure 4: CyberKnife

2 Uses

The use of robots in medicine has expanded to all areas of surgery. Robots are favorable because of their high accuracy, lack of tremors, do not tire, can be sterilized, and can perform more risky operations without risk of injury. Robots also offer quicker recovery to the patient and less invasive surgery. Robots can be used to make smaller incisions, which take less time to heal. Robots have spread into countless fields of medicine because of their favorable attributes over a human; however, robots are particularly prominent in orthopedics, neurology, and cardiology.

2.1 Robots in Orthopedics

Robots are most commonly accepted and used in Orthopedics because of the effectiveness robots offer with bones. Bones can be pressed on without risk of deformities making robots best fit for working with bones. Furthermore robots can accurately map bones and use the map for the most effective placement of orthopedics such as hip replacements. Prior to the use of robots in orthopedic surgery, patients risked misplacement and poor long term results.

In computer aided orthopedic surgery the operation involves three main objects and procedures. The objects include: the patient, the virtual representation of the patient, and the navigator. While the

procedures include: end effectors calibration, registration, and dynamic referencing. The virtual representation of the patient is usually a CT scan and the navigator is a machine that allows the surgeon to operate the robot. End effectors calibration creates the correct representation of surgical instruments or devices and puts them in a coordinate system. Registration is the process by which correspondence between the patient and computer generated image is created. In this stage the virtual is lined up with the patient to allow the robot to operate. Finally in dynamic referencing a coordination system is created that compensates for possible motion of the surgeon or the patient.

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2.2 Robots in Neurology

By the early 1980s, there was a demand for new technology to aid in neurosurgery. The surgeries were becoming too complex to be carried out by even the best trained human hands. During this same time vast improvements had been made in computer technology, engineering, minimum invasive surgery, and neuroimaging techniques. Out of these advancements the concept of using robots in neurosurgery was born. The demand for high accuracy and the fixed anatomy of the brain led Neurosurgery to be one of the first organ systems in which robotic surgeries were introduced. Robots have now become crucial to neurosurgery because of the precision they offer at the microscopic level.

Robots used in neurosurgery consist of the following basic parts: robotic arm, feedback sensors, controllers to guide the robot, a wireless localization system, and a data processing center. Robots offer the neurosurgeon many advantages. The most important advantage is the ability to work precisely on a microscopic level. Also robots greatly increase accuracy and precision, reduce invasiveness leading to quicker recovery, can process more data than a human, can work under the control of a human, and eliminate the danger of a tremor inevitable in human surgeons. Such advantages are particularly important in neurosurgery because the brain is vital to life and very delicate.

2.3 Robots in Cardiology

Robots have expanded into cardiology because of the demand for shorter recoveries. In some patients the fastest recovery was delayed because of health risks. Now, however, with the development of medical robots quicker surgeries are available. Such systems as the Da Vinci have made robots in cardiac surgery more useful. Robots can be said to have entered cardiology in four increasingly complex levels. The first level is Direct Vision and Mini-Incisions. In this level robots are used to reduce invasion then convention methods of operation are used for the surgery. The second level is Video-Assisted and Micro-Incisions. In this level robots are used to enlarge the view of surgeon for simple repairs and replacement surgeries. The third level is Video-Directed and Port Incisions. This

stage brings the integration of a robotic arm into the process again decreasing invasiveness. The final stage is Video-Directed and Robotic Instruments. This stage involves the use of 3-D imaging and robotic equipment. 3-D imaging allows for the most complex cardiac surgeries to be performed with fewer invasions. Much of the development in this stage has come due to the Da Vinci robot.

3 Robots in the Future

Robots in the operating room provide more precision and mobility than a surgeon, but the technology is so recent that many hospitals can not afford it. But as time goes on, further changes to Robotic Surgical Systems will improve as technology improves. One such improvement is the addition of a special endoscope. This endoscope would allow the surgeon the ability to zoom in and out without having to move the scope, which greatly increases a patient's safety because the surgeon can see more in less time. Also, the option of adding more arms to the Surgical System is another feature producers are looking into for greater control.

The United States military has designed a portable Robotic Surgical System called the Life Support for Trauma and Transport (LSTAT)[5]. The LSTAT is a monumental step in the direction towards a future where robots dominated the medical field. The LSTAT provides an intensive care unit in an easily transportable package. This system could save many more lives on the battlefield. The LSTAT could also be modified to be used in hospitals or nursing homes to allow the patient greater mobility and independence.

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