NEW FRONTIERS IN LAPAROSCOPIC SURGERY : ROBOTIC SURGERY

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Abstract : *Robotic surgery is* ***computer-aided surgery*** *which provides secure and precise procedure that the operator wants. The surgeon has control over the system's functions by means of a computer interface that creates an instinctive environment when he is sitting at the console. The movement of the instruments is controlled by motion-scale function, elimination of tremor, remote master-slave manipulator system. Robotic surgery can be used for a number of procedures including: general surgery (i.e. laparoscopic adrenalectomy, gastric bypass), gynecological surgery (i.e. cystocele repair, hysterectomy, tubal ligation), thoracic surgery (esophagectomy, lung biopsy, tumor resection), urological surgery (donor nephrectomy, prostatectomy, and ureter harvest), vascular surgery (aortic abdominal aneurysm and vena cava tumor).*

"Robotic surgery is not a transition technology, as is laparoscopic surgery, but it is the fulfillment of the promise that was begun by laparoscopic surgery."

- Richard Satava

INTRODUCTION

Since the widespread introduction of minimally invasive surgery (MIS) in the early 1990s, initially with laparoscopic cholecystectomy, extensive evidence has demonstrated its advantages over open surgery – faster recovery with less pain and fewer complications. The reason why MIS is so explosively popularized all over the world is that there is a significant difference in postoperative quality of life of the patients with MIS from that with open surgery. The patients who underwent MIS not only had less incision on the skin surface or less postoperative pain, but also could receive earlier recovery to normal life or normal activity after MIS than after conventional open surgery.

DISADVANTAGES OF LAPAROSCOPIC SURGERY

Although there are clear benefits, MIS also has some disadvantage for the surgeons. Long instruments placed through fixed entry points creating a fulcrum effect, the surgical field viewed on a 2-D screen and with the camera under an assistant's control, create an unnatural environment where the surgeon loses orientation, the eye –hand-target axis, and visual depth perception. All these obstacles reduce the surgeon's normal dexterity and limit his ability to deal with difficult situation. Surgeons are now put into a tough condition since more strict and correct preoperative evaluation of the patients, less complication rate or less operation mistakes are mandatory. Because it is different from open surgery, once complications occurred it led to more invasive major operation, followed by a life-threatening incident. This new phenomenon was due to MIS. It is mainly because of the technical difficulties in movement of instruments or limitation of surgical field through the endoscope, and no tactile sensation or force feedback sensation. The surgeon has to perform complex procedures such as intra-corporeal ligature or suturing in the limited condition. However, a systematic training system has not yet been established for MIS all over the world because MIS had developed so quickly since early 1990s.

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RISE OF THE ROBOTIC SYSTEMS

More recently, robot-assisted surgery has emerged as a popular method. Robotic arms allow the surgeons for finer control and remote presence and provide a computerized interface between the patient and the surgeon. Nearly all the manipulations of robotic surgery are performed by fingers, hand and wrist, while laparoscopic surgery is performed mainly with the wrist, forearm and shoulders. This makes the robotic systems inherently more precise and dexterous, since the fingers, hands and wrist have more than 25 degrees of freedom and the wrist, forearm and shoulder have only 8 degrees of freedom. The human hand is used for precision and dexterity, while the arm and shoulders are used for power.

DEFINITION OF ROBOT

The word "Robot" is taken from the Czech robota, meaning forced labor, has evolved in meaning from dumb machines that perform menial, repetitive tasks to the highly intelligent anthropomorphic robots of popular culture. The term was coined in K. Capek's play R.U.R. "Rossumi's Universal Robots" (1920)

DEFINITION OF ROBOTIC SURGERY

Robotic surgery is the use of robots in performing surgery. Three major advances aided by surgical robots have been remote surgery, minimally invasive surgery, and unmanned surgery. Major potential advantages of robotic surgery are precision and miniaturization. Further advantages are articulation beyond normal manipulation and three-dimensional magnification.

HISTORY

The history of surgical robotics begins with the Puma 560, a robot used in 1985 by Kwoh et al to perform neurosurgical biopsies with greater precision. Three years later, in 1988 Davies et al performed a transurethral resection of the prostate using the Puma 560. This system eventually led to the development of PROBOT, a robot designed specifically for transurethral resection of the prostate, at Imperial College, London.

In 1992, ROBODOC, a robotic system was designed to mill out precise fittings in the femur for hip replacement surgery. ROBODOC was the first surgical robot approved by the FDA. Intuitive Surgical Inc. carried out further development of robotic systems, with the introduction of the Da Vinci Surgical System and Computer Motion Inc. with the AESOP and the ZEUS robotic surgical systems. Later in 1994, Intuitive Surgical purchased Computer Motion and discontinued development of the ZEUS System.

Dr. Ralph Damiano at the Milton S. Hershey Medical Center, Pennsylvania performed the first coronary bypass surgery in a human patient using robotic arms.

Today, the Da Vinci System is FDA cleared for a variety of surgical procedures including surgery for prostate cancer, hysterectomy and Mitral valve repair and used in over 800 hospitals in the Americas and Europe. The Da Vinci System was used in at over 48,000 procedures in 2006 and sells for about 1.2 million dollars.

WHAT IS THE DA VINCI SURGICAL ROBOTIC SYSTEM?

The robotic surgical system is a computer-enhanced minimally invasive surgical system consisting of three components:

1. Robotic Cart
2. Surgical Console
3. Endoscopic Instrumentation stack

The system has technical features which significantly augment the quality and control of the visual field and thus enhance the dexterity of the surgeon. It delivers a high quality three dimensional (3-D) vision to the surgeon manning the console. This technology allows intuitive telemanipulation with tremor abolition, motion scaling and endo-wristed instruments. This is essentially what gives this technology an edge over the endoscopic technology which has been prevailing over the last 2 decades and overcomes some of the pitfalls of conventional laparoscopy which have probably limited the capabilities of the surgeon in the field of minimally invasive surgery[15].

This technology has been proposed to overcome some of the drawbacks of traditional MIS i.e.

a) Two dimensional imaging
b) Motion restrictions
c) Motion scaling
d) Poor ergonomics

This technology includes master-slave tele-manipulator systems. The goals of these surgical systems are to enhance manipulation capabilities and to increase the performance precision. Robotic surgery is what is called Computer-aided surgery. It provides secure and precise procedure that the operator wants. The surgeon has control over the system's functions by means of a computer interface that creates an intuitive (Instinctive) environment, when he is sitting at the console. The movement of the instruments is controlled by motion-scale function, elimination of tremor, remote master-slave manipulator system. The self fail system is supported by checking the total system about 1200 times every second, or by quick retrieval of the instrument from the body and it allows us to shift to conventional surgery within 10 seconds.

ROBOTIC CART

The robotic cart of the da Vinci system is composed of three or four mechanical arms attached to a mobile base, which is connected to the operating console via a cable. The center arm holds the camera system and the two lateral arms hold the surgical instruments. The camera arm grasps a disposable standard 12mm port and the camera unit, which passes through it. The lateral arms attach to special 8mm metal ports supplied with both blunt and sharp trocars. The cart is locked in place but is not attached to the operating table. The whole system runs off the main power system and has a 5- minute internal power backup. The central arm holds and moves the camera system (Insite vision system, Intuitive Surgical, Inc.). There are zero-and 30-degreee cameras (looking up or looking down) available. The camera has a dual lens system with two-three-chip cameras housed and spatially separated within one 12-mm casing. Thus, two complete optical systems are incorporated, representing the left and right eyes. The projection of the two spatially separated images in the binocular viewer allows true 3-D image perception at the console.

There is a range of instruments available with the system, which can be easily and rapidly changed by the assistant surgeon. There are 6 degrees of freedom at the instrument tip and a 7th degree of freedom is supplied by the action of the instrument itself (e.g. cutting or grasping). The instruments are designed to mimic the movement of the surgeon's hands, wrists and fingers.Their extensive range of motion allows precision that is not available in standard minimally invasive procedures.

Surgeon console containing the master controls that the surgeon uses to manipulate the instruments. The handles or "Masters" translate the surgeon's natural hand and wrist movements into corresponding, precise and scaled movements. The instruments are only able to move when commanded by the surgeon. The surgical console consists of the binocular viewer of the Insite vision system, the instrument controllers, the system setup and control panels, and a series of foot control pedals.

ENDOSCOPIC INSTRUMENTATION STACK

The endoscopic stack incorporates all the features of a standard endoscopic stack: a monitor, a CO_2 insufflator, a light source, and a camera unit. There is a 2-D monitor for the benefit of the scrub team, assistant surgeons, and observers. The light source comes from two high-intensity illuminators. There are two camera control units, two image synchronizers, and a focus controller that allow the production of the high quality 3-D image at the console.

BENEFITS OF ROBOTIC SURGERY

Benefits to Patient

- Reduced pain and trauma to the body
- Less blood loss and need for transfusions
- Less post-operative pain and discomfort
- Less risk of infection
- Shorter hospital stay
- Faster recovery and return to work.
- Allows for a minimally-invasive approach in surgery which means much less scarring and improved comesis

Benefits to surgeon

- Greater precision and dexterity
- Where fine suturing techniques are required
- Robotic arms eliminate the tremor of a surgeon's hands
- Improved technique for surgery
- Reduced fatigue during surgery
- Comfortable seated position at robotic controls.

Limitations

- Current equipment is expensive to obtain, maintain, and operate
- If one of the older model non-autonomous robots is being used, surgeons and staff need special training
- Data collection of procedures and their outcomes remain limited

WHAT ALL A ROBOT CAN DO FOR SURGEONS?

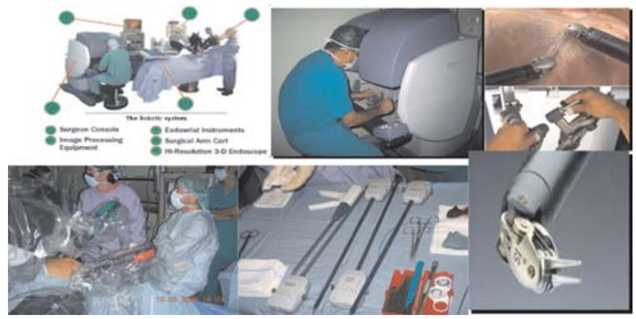
Robotic surgery can, in fact, be used for a number of procedures within multiple specialties including: general surgery (i.e. laparoscopic adrenalectomy, gastric bypass), gynecological surgery (i.e. cystocele repair, hysterectomy, tubal ligation), thoracic surgery (esophagectomy, lung biopsy, tumor resection), urological surgery (donor nephrectomy, prostatectomy, and ureter harvest), vascular surgery (aortic abdominal aneurysm and vena cava tumor). There are no laparoscopic procedures that can be performed by Robotic surgery. There are a number of emerging robotic procedures that will not be able to be performed by laparoscopic technique.

However, the number of surgical applications of robot-assisted surgery are increasing slowly, mainly due to the high investment and running costs of the devices even though the initial benefits exist. But new applications must be developed as the full range of robotic application is still to be implemented. The initial concept of robotics in surgery involved operating at a remote site from the surgeon. The ability to transpose surgical and technical expertise from one site to a distant site (i.e.: proctorship, assisting developing country or remote area like) was thought to expand surgical application. Although simple surgical procedures have been performed remotely, there are some difficulties for an extensive clinical use because of high costs, transmission delay and medical and legal issues.

THE LEARNING CURVE

The FDA requires manufacturers to train surgeons before they can use robotic surgical systems on patients. Ogden says there is a significant learning curve involved. "As it stands now, it takes 12-18 patients before surgeons feel comfortable and before surgeons are able to perform the procedures as quickly as with standard techniques," he says.

Paul Nolan of Computer Motion says typical training for surgeons who buy the ZEUS system involves up to 40 hours, including experience at animal and cadaver labs.



THE FUTURE OF ROBOTIC SURGERY

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.

Telerobots may also serve as the assistant surgeon as well as the operating surgeon. Telemedicine, telerobotics and virtual reality systems are rapidly evolving in conjunction with the rapid growth of the capabilities of computer systems.

By providing the use of a variety of technologies to enhance the capabilities of human surgeons, robotics will become an increasingly vital component in the medical world. Doctors of the next century must learn to use this information to complement their capabilities in order to provide better patient care.

RECOMENDED READING

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