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Robotic Assisted Microsurgery (RAMS): Application in Plastic Surgery

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1. Introduction

The essence of plastic surgery is to have innovative thinking, capacity to find new methods and to adopt newer technologies to its benefit. The development of medical robotic system to assist surgeons in various surgical specialties is a new advancement and is a growing field of telerobotic research. The Robotic Assisted Microsurgery (RAMS) represents one of the latest innovations of telerobotics in the microsurgical field and with the continuing success of Robotic Assisted Microsurgery in various surgical specialties, the plastic surgeons have started exploring its application for performing technically challenging, time consuming and physical exhausting micro-vascular procedures. RAMS represents an advanced application of telerobotic surgery and a possible answer to the surgeon's demand for ways to overcome the surgical limitations of microsurgery. Basically the RAMS system is a telerobot with mechanical arms which is controlled by a computer but operated by a surgeon. RAMS allows performing high dexterity microsurgical operations with the help of robotic arms and improves microsurgery through tremor filtration, articulation, motion scaling, and improved ergonomics. The surgeon actually does a better, more precise, dexterous and highly controlled microsurgical procedure under high magnification resulting into optimal microsurgical outcome. This chapter reviews various developments in the field of robotic microsurgery and discusses various aspects related to human versus robotic microsurgery and its potential use in plastic surgery.

2. History of telerobotics

A robot is defined as a sensor-based tool capable of performing precise, accurate and versatile actions on its environment. In medicine, robots have recently evolved into complex systems integrating perception (medical images and information) and action (precise spatial positioning and sensory feedback) by mechanically controlled systems and image-guided devices (Brady & Paul, 1984) resulting in their practical utility.

The telerobotic era started in the early 1990's when NASA's jet propulsion laboratory (JPL) began a project in telerobotics as part of its emergency response robotic program. The primary aim was to develop a robotic system (HAZBOT) to allow safe exploration of potentially dangerous sites (defusion of bombs, nuclear warfare, battle sites) and handling of hazardous materials (wastes from nuclear reactors)(Edmonds &Welch ,1993)(Figure-1). The concept was also looked at by the military strategists who envisioned a situation where

surgeons could operate remotely on casualties without ever having to enter the combat zone (Cubano et al, 1999) .The engineers from NASA and the JPL also intended this concept for telesurgery in space to enable surgeons on earth to operate on astronauts at the space station. The time lag, however, prevented this from becoming feasible. The development of telerobotic technology was subsequently accelerated by various concomitant advancements in computer and surgical related technology. However, for a long time, placing dexterity enhancing robotic systems in the operating room remained an elusive goal. The further evolution of the robotic surgical system culminated in the development of a different skill and advanced instrumentation resulting in feasibility of the concept.
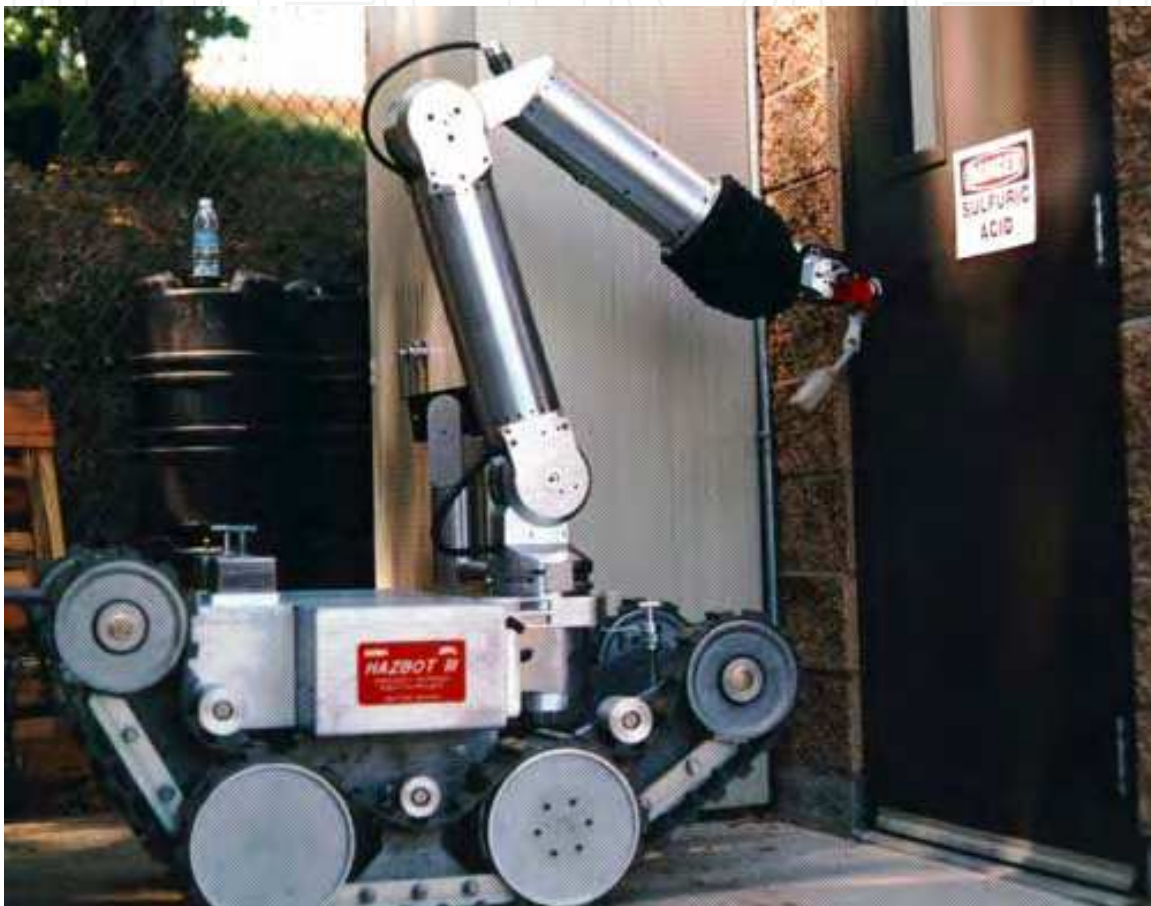

Figure 1. HAZBOT,"Courtesy NASA/JPL-Caltech"

3. Development of robotic surgical technology

In the mid 90's there was a sudden surge in the development of robotic surgical technology. The Computer Motion, a medical robotic company founded in 1989 played a pivotal role in developing early surgical robotic technology (Bushnell P,2001). Their first product was Aesop; a robotic system used for holding an endoscopic camera in minimal invasive laparoscopic surgery and became the first surgical visual aid robotic device certified by the FDA. Aesop 2000 was released in 1996 which used voice control, the Aesop 3000 was released in 1998 which added another degree of freedom in the arm, and the Aesop HR version was networked with other smart devices. The Zeus Robotic Surgical System with three robotic arms attached on the side of the operation table was developed as an extension

of Aesop arms to control surgical instruments. The first prototype was demonstrated in 1995, tested in animal in 1996 with first tubal re-anastomosis and first CABG procedure carried out in 1998. After 2000, Micro-wrist and Micro-Joint were also added. Micro joints in Zeus were designed to hold 28 different instruments including scalpels, hooks to tie knots, scissors and dissector. The Zeus system got FDA approval in 2001. One of the major contributions of Computer Motion to the field of digital surgery was Zeus capability to digitally filter out human hand tremor making the robotic procedure more steady and reliable. The system was designed for minimally invasive microsurgery procedures, such as beating heart, endoscopic coronary artery bypass grafting and initiated more complex procedures like a mitral valve surgery (Robotic Surgery, 2005).

In 1992 Integrated Surgical Systems introduced RoboDoc for orthopedic surgery and first robot-assisted human hip replacement was successfully done on a 64-year-old man suffering from osteoarthritis.

In 1995 Intuitive Surgical, another company in the field of robotic surgery was formed based on foundational robotic surgery technology developed at Stanford Research Institute. In a short time the company collaborated with leading institutions and companies like IBM, Massachusetts Institute of Technology (MIT), Heartport Inc., Olympus Optical, Ethicon Endo-Surgery and came up with the da Vinci System. In 1997 da Vinci Surgical system got FDA approval for assisting surgery and in July 2000 the da Vinci Surgical system became the first laparoscopic surgical robotic system that got cleared by the FDA to perform surgery. (Figure-2). Then market forces dictated further innovations. The Computer Motion and Intuitive Surgical companies finally merged into a single company, Intuitive Surgical in 2003.

In the da Vinci system, the surgeon sits at a viewfinder (left) and remotely manipulates probes and instruments on actuator arms over the operating table

Figure 2. The da Vinci system, "Courtesy Intuitive Surgical"

With the release of the da Vinci System ,Intuitive's major contributions to the history of robotic surgery is the 'EndoWrist', a miniaturized hand, and the control system, reproducing the range of motion and dexterity of the surgeon's hand, providing high precision, flexibility and the ability to rotate instruments 360 degrees through tiny surgical incisions(Robotic Surgery,2005)(Figure-3). Later seven degrees of freedom were added which offered considerable choice in rotation and pivoting (Camarillo et al, 2004). The da Vinci Surgical System replicates the surgeon's movements in real time. It cannot be programmed, nor can it make decisions on its own to move in any way or perform any type of surgical maneuver.

Figure 3. Endowrist,"Courtesy Intuitive Surgical"

The FDA cleared da Vinci Surgical system for use in performing many surgical procedures including general laparoscopic surgery, thoracoscopic (chest) surgery, laparoscopic radical prostatectomies, and thoracoscopically assisted cardiotomy procedures (Robotic Surgery, 2005).

The robotic arm is the end-effector of robotic systems and the continuing development of robotic arms remains the foundation of telerobotics research. This involves the integration and application of haptics, engineering neurobiology, cognitive science and computers (Le Roux et al, 2001). The ongoing research aims to evolve compact but more efficient, more dexterous, more maneuverable surgeon friendly robotic arms with more degrees-of-freedom.

4. Development of the Robotic Assisted Microsurgery (RAMS)

While the early writing on the new technology covered a variety of surgical procedures, special attention was given to cardiovascular procedures. In the mid nineties, Steve Charles, a vitreoretinal surgeon, originated the concept of a telerobotic system as a tool to assist the microsurgical procedures (Turner et al, 1997). Subsequently, in 1994-95 JPL engineers developed RAMS based on surgical requirements provided by Steve Charles using previously developed NASA telerobotics technology (Figure-4). It was a six-degrees-of-freedom surgical robot slave made up of a torso-shoulder-elbow body with a three-axis wrist. The robot manipulator was about 10 inches long and 1 inch in diameter.
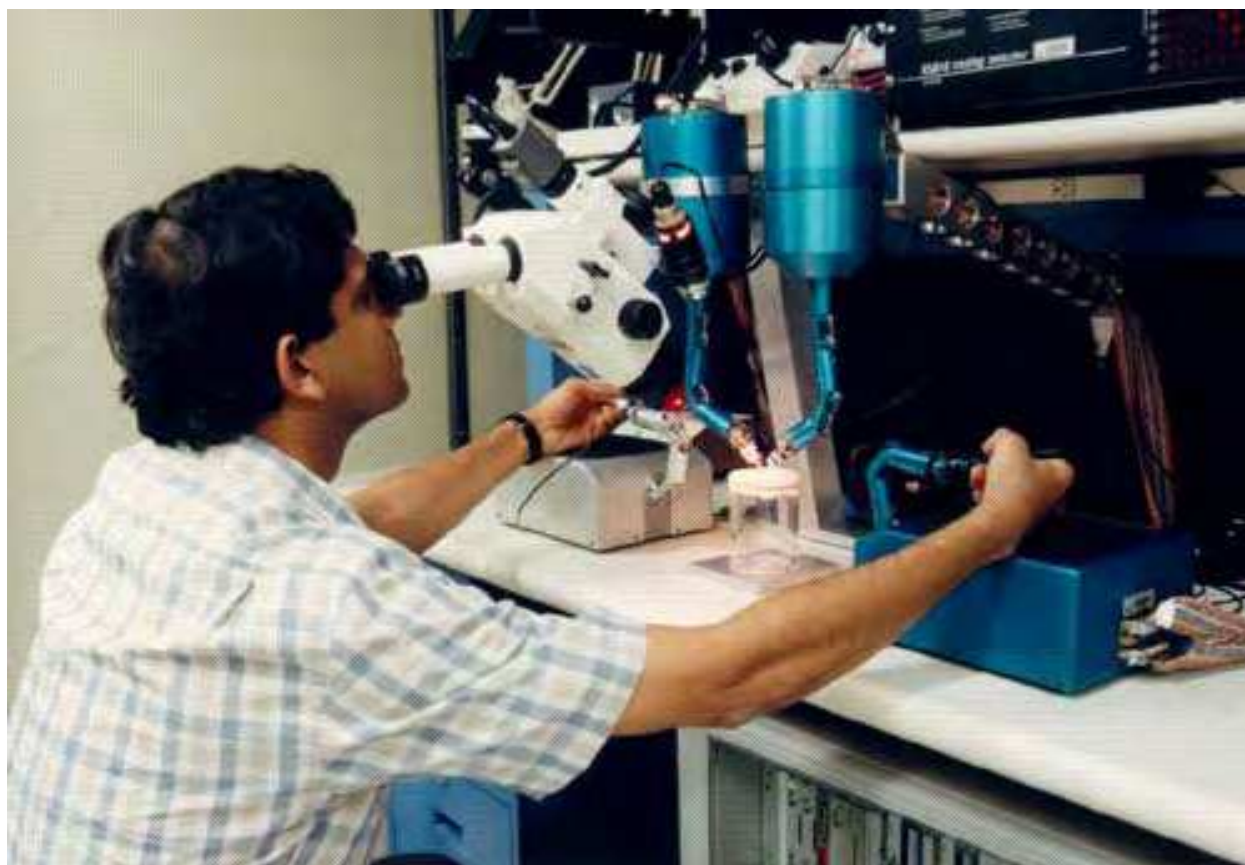
Figure 4. RAMS: Robot Assisted Microsurgery," Courtesy NASA/JPL-Caltech"

In 1998, a study by Stephenson first pointed out to the fact that coronary artery anastomoses are technically feasible with the use of robotic instruments(Stephenson et al,1998).An additional study done by the same group reported the successful use of this approach in a large animal trial(Schaff,2001). Further studies of the feasibility of endoscopic cardiac surgery was performed by various surgical teams verifying that robotic technology could be used to accomplish a completely endoscopic anastomosis (Le Roux et al,2001;Szymula et al,2001;Schiff et al,2005).

Additional studies involving cardiac procedures have also produced positive findings with regard to the clinical efficacy and benefits of robotic assisted anastomosis. In 1999, Schueler performed the world's first closed-chest multivessel cardiac bypass using the daVinci system (Stephenson et al, 1998). In September 24, 1999 Dr. Boyd performed the world's first robotically-assisted closed-chest beating heart cardiac bypass operation using the Zeus system.

Mohr et al first used the da Vinci Robotic system and the AESOP system for ITA harvesting and CABG surgery (Mohr et al,1999). On July 11, 2000, FDA approved the first completely robotic surgery device, the da Vinci surgical system from Intuitive Surgical to perform general surgical procedures while seated at a computer console and 3-D video imaging system across the room from the patient(Stephenson et al,1998). The da Vinci used technology that allowed the surgeon to get closer to the surgical site than human vision, and worked at a smaller scale than conventional surgery permitted. The da Vinci's Surgical System integrated 3D HD laparoscopy and state-of-the-art robotic technology to virtually extend the surgeon's eyes and hands into the surgical field. The da Vinci later incorporated

the latest advancements in robotics and computer technology to enable minimally invasive options for complex surgical procedures.

In 2000, a German study found out that using the daVinci system to perform endoscopic beating heart (single or double) bypass surgery is safe, causes significantly less trauma to the patient and allows for quicker recovery. In another study with a prototype RAMS, 10 carotid arteriotomies were created and closed using either the RAMS system or conventional microsurgical techniques. The precision, technical quality and error rate of telerobotic surgery were similar to those of conventional techniques but it was found to be associated with a twofold increase in the length of the procedure (Le Roux et al, 2001). Later, many studies were performed to evaluate the effectiveness of the Zeus system in performing complex, open, microsurgery tasks in various animal models. A study done in 2000 concluded that concurrent use of the RAMS as a microsurgical assistant is applicable in microsurgery, with the advantages of greater precision and more rapid microsurgical manipulation(Siemionow et al,2000).

An important comparative RAMS study was performed by several international scientific teams to analyze various features related to micro-vascular anastomosis. This comparative study was carried out between RAMS and surgeon performing anastomosis with 3-D endoscope. The mean total operative time per 3 mm robotic anastomosis, utilizing 9-0 suture using 2-D visual port was 29.5±15 minutes (excluding setting up and dismantling robotic arms). The mean total operative time per 3 mm surgeon anastomosis using 3-D endoscope was found to be 16.3±5 minutes. The inference was, though the robot took longer time for anastomosis, they performed high quality, tremor free precise microsurgery without any technological problem and intraoperative complications (Schenker et al, 2001).

In 2004, FDA cleared the marketing of a robotic-like system to assist in coronary artery by-pass surgery enabling the surgeon to perform heart surgery while seated at a console with a computer and video monitor.

A study done in 2005 compared the micro-vascular anastomoses performed with a robot-enhanced technique (31 anastomoses) with a standard hand technique (30 anastomoses) on 1-mm rat femoral arteries with interrupted 10-0 suture(Knight et al ,2005).They compared the anastomotic time, patency, and leak rates between traditional microsurgery techniques (by hand) and a robot-enhanced technique using the Zeus robotic surgery system. A remarkable degree of tremor filtration was observed in the robot-enhanced cases. All anastomoses from both groups were found patent, however, the anastomoses done by hand (mean time, 17.2 minutes) were significantly faster than those done with Zeus (mean time, 27.6 minutes). They concluded that the Zeus system is effective at performing complex, open, microsurgery tasks in vivo.

Another Japanese study in 2005 successfully demonstrated the closure of a partial arteriotomy and complete end-to-end anastomosis of the carotid artery in the deep operative field performed on 20 rats (Morita et al , 2005). A study was undertaken in 2005 to see the feasibility of doing free flap in a porcine model by surgical robot .The free flap was successfully performed. The advantages conferred by the da Vinci robot were found to be elimination of tremor, scalable movements, fully articulating instruments with six degrees of spatial freedom and a dynamic three-dimensional visualization system. The drawbacks included the cost and the absence of true microsurgical instruments (Katz et al, 2005).

A study conducted on canine tarsal and superficial femoral vessels at The Johns Hopkins University School of Medicine, Baltimore in 2006 demonstrated the success of da Vinci robot

to perform micro-vascular anastomoses (Katz et al 2006). A study conducted on pig models in 2006 also demonstrated the technical feasibility of performing a safe and efficient robotic-assisted microsurgical anastomosis but took longer anastomotic times with robotic assistance [Robot: 14.0 versus Freehand 14.8 minutes](Karamanoukian et al,2006).

Technical details of Surgical Robot The typical surgical robot architecture follows a classical mater/slave tele-operation set up. This set up consists of two modules: the surgeon console (master) and the robot (slave). The surgeon's console is both viewing and active computer controlled console having set of ergonomically designed handles along with integrated 3-D vision system and in some cases voice command components. High resolution optical encoder is selected for transmitting the command from master arm to slave arm. The surgeon, sitting at the control console analyze the 3-D images sent by the camera inside operating room. The robotic system interacting with the patient includes usually three robotic arms; two to manipulate the surgical instruments and a third to position the endoscopic camera at the optimal position. The surgeon controls the position of the robotic arms and in turn surgical instruments via joystick-like controls at the console and third endoscopic camera arm by voice command, providing the surgeon precise and stable view of the actual surgical field. Each time a joystick moves, computer transmits an electronic signal to the respective surgical instrument, which moves in complete synchronization with the movements of the surgeon's hands.

5. Configuration of RAMS system

Surgeon
- Surgeon's console (Master)
- Robotic arms (Slave)-2 arms
- Microsurgical instruments

Endoscopic camera

- Visualization of operating field

Robotic arm (voice activated)-3rd arm

- Endoscopic camera

Assistant/nurse

- For setting robotic arms
- For changing instruments

6. Robotic Assisted Surgery

The development of telerobotic system to assist surgeons is a growing field of research. The quickly expanding field of telerobotics with faster processors and new algorithms has lead to a significant paradigm shift from performing open surgeries to minimally invasive procedures. The robotic technology has started moving from the developmental phase to the application phase. Robots are becoming revolutionary tools for surgeons in a variety of clinical applications. Robots are increasingly being used in laparoscopic surgery(Marescaux et al, 2001), urological surgery (Hoznek et al, 2002; Menon, 2003, Menon et al, 2004) neurosurgery (Le Roux et al 2001; Zimmermann et al, 2002) and cardiac surgery with

varying success (Schenker et al, 1994; Stephenson et al 1998; Tang et al 2001). They have also been successful employed in orthopedic surgery to perform total hip arthroplasty surgery (Taylor et al, 1994)). Robotic surgery offers many benefits over conventional surgery which includes reduced trauma, less blood loss, less post-operative pain, shorter hospital stay, faster recovery and early return to work.

The other exciting aspect of robotic technology is teleconsultation and tele proctoring. With the help of internet the robotic system can be linked to another surgeon with more expertise in another institute/country when one surgeon encounters difficulty or a more experienced surgeon can act as a preceptor for less experienced surgeon. The Telerobotic surgery will also be particularly suited to countries with a high technological and medical expertise possessing a number of remote communities who could be potential beneficiary of this technique (Dasgupta & Challacombe, 2005).

In robotic surgery, the robots are not independently automated opearators. They are highly advanced teleoperated systems which are under direct control of the surgeon (Cavusoglu et al, 2003). They work basically as manipulators, working on a master-slave principle and have nothing in common with the science fiction robots. Robots can be defined as "automatically controlled multitask manipulators, which are freely programmable in three or more spaces." The success of robots in surgery is based on their precision, lack of fatigue, and speed of action (Moran, 2003).

7. Robotic Assisted Microsurgery-Advantages

The term robotic surgery probably gives an impression of a Robot independently operating on a patient in operation theatre. This image is not correct as they do not replace the surgeon at all in the operation theatre. They only maneuver the surgical instruments necessary for surgery and are always under the direct, total control of the surgeon. The RAMS workstation is a precise tool and can assist the surgeon as a "second" or "third hand". It cannot entirely replace the microsurgical instruments held by the surgeon (Krapohl et al, 1999). As JPL's Tom Hamilton rightly commented "RAMS takes the most skilled surgeon and makes his or her skills better. RAMS can improve surgical techniques to allow faster and safer procedures" (Hamilton, 1997). This option of performing high precision surgery has sparked the potentially huge hope for its application in doing micro-vascular surgery in plastic surgery. Microsurgery is a specialized technique which requires many years of training to be proficient. In microsurgery, the instruments virtually become specialized extensions of the surgeon's hands. As the surgeons differ in hand steadiness, dexterity, maneuverability and technical quality, the outcome of microsurgery is limited by the individual surgeon's manual dexterity. Further, surgical performance varies during the procedure or throughout an individual surgeon's life time. The role of robotic automation is to standardize the procedure and the surgical robots can reduce the variations in the patient outcome among surgeons and for an individual surgeon.

During microsurgery the surgeon has to manipulate tissue with the instruments and the result is likely to be the affected by individual surgeon's dexterity. In addition, several factors such as lengthy period, time constraint and tremors during the procedure can adversely affect the surgeon's technical performance. As the current microsurgical practice is now challenging the limits of human dexterity, stamina and patience, the limiting factors basically arise due to undesired involuntary and inadvertent movement of

the hand which creates an error component in hand motion (Riviere & Khosala, 1997). The most familiar source of undesired hand motion is physiological tremor which is an approximately rhythmic, roughly sinusoidal involuntary component inherent in all human motion (Elble, 1996). Low frequency errors or drift are also present in hand motions and are often longer than tremors (Riviere et al, 1997). Irregular high-frequency motions or jerk can also occur (Schenker et al, 1995). The results are that some movements are less precise than is desired and some desired movements cannot be done at all. Microsurgical practice would therefore benefit greatly from RAMS that enhance accuracy by compensating position error. RAMS is based on typical master slave tele-operation. Using RAMS, the surgeon sitting on the console orchestrates or commands the motions of the robotic arms to perform microsurgical procedures. The surgeons hand motions are transferred in a real-time through a computer system, where they are processed to automate the robotic movements. This process reduces the surgeon's movement at the tissue level and prevents tremor or inadvertent movement often associated with fatigue, anxiety, age related or other factors.

The following table (Table-1) compares the strengths and limitations of Humans and Robot (Howe & Matsuoka, 1999):

Humans	Robots
Strengths	Strengths
Strong hand-eye coordination	Good geometric accuracy
Dexterous (at human scale)	Stable and untiring
Flexible and adaptable	Can be designed for a wide range of scales
Can integrate extensive and diverse information	May be sterilized
Able to use qualitative information	Resistant to radiation and infection
Good judgment	Can use diverse sensors (chemical, force, acoustic, etc.) in control
Easy to instruct and debrief	
Limitations	Limitations
Limited dexterity outside natural scale	Poor judgment
Prone to tremor and fatigue	Limited dexterity and hand-eye coordination
Limited geometric accuracy	Limited to relatively simple procedures
Limited ability to use quantitative information	Expensive
Large operating room space requirement	Technology in flux
Limited sterility	Difficult to construct and debug
Susceptible to radiation and infection	

[a]Adapted from Taylor & Stulberg (75).

Table 1. The strengths and limitations of Humans and Robot

The advantages of RAMS are thus obvious. As hours of exacting work can tire anybody, superior ergonomics while seated at the console optimizes the surgeon's performance and dexterity. Any tremor in the surgeon's own hands and fingers is completely eliminated with the help of tremor filters and motion scalers leading to superior dexterity (Louw et al, 2004). Another important feature is that there is greatly increased precision due to scalability of movements which can be up to 1:6 scale, meaning that six mm movement of fingers will result in 1 mm movement of the instrument (Rosson, 2005). This increased precision is of great importance during microsurgery, with complete elimination of hand and finger tremors. These qualities allow an average surgeon to perform at par with the best surgeons and allow the skillful surgeons to perform at unprecedented levels of dexterity.

Another feature is that one can always find the perfect angle towards the vessel due to enhanced rotating ability of the camera and wrists of the robotic arm. RAMS also provides more range of motion and more degree of freedom than the human hand leading to easy maneuverability in difficult positions. It can virtually be viewed as a specialized extension of the surgeon's hands. Other added features like optimal magnification with 3-D visualization, superior resolution and 3-D spatial accuracy mark the characteristics of RAMS. This indefatigable nature of RAMS is likely to be of enormous help in performing vascular anastomosis especially in cases of free flaps, digital replantations, microneurorrhaphy and other similar demanding microsurgical procedures (Rosson, 2005).

It also has a potentially invaluable use during microsurgery involving high risk patients /patients with HIV, to protect the surgeon from virus transmission.

8. Robotic Assisted Microsurgery-Limitations

Despite of all mentioned advantages, there are some limitations too. Although reproducible in ex-vivo model, more clinical trials will be required to explore its full potential in clinical micro vascular practice. The initial capital cost ranging from one million to several million dollars is prohibitive for its free use. The average base cost of the da Vinci System is $1.5 million. However, multi-specialty utilization of robotic technology along with improvement in surgical outcome and more expeditious return to work will make this approach cost-effective, justifying investment in this technology. The use of the robots by many specialties will bring down the cost of investment and will make them more cost effective for use in micro vascular surgery. The improved accuracy in microsurgery will ultimately be reflected in improved surgical outcome thus justifying their use (Karamanoukian et al, 2006).

However the system has inherent limitations too. The present systems are cumbersome and there is potential interference between the robotic arms and loss of tactile feedback. The proper functioning of computer software component which is a "command central" for the device's operation is also essential for error proof working of the surgical robot. The other limitation is that there is no haptic feedback which often makes the surgeon feels detached from the patient and the procedure. However, high magnification of operative site negates this draw back(Rosson ,2005).There is also a learning curve but after dedicated training and some experience, one feels comfortable working with the instrumentation and doing the surgery without actually touching the patient. Surgeons may require surgical reeducation and familiarization with a whole new set of complex

skills and recent studies are indicating that robotically assisted microanastomosis can be mastered equally well by surgical trainees and fully trained vascular surgeons and prior experience in performing microsurgery is not all that significant factor (Karamanoukian et al 2006). The time taken for the surgery is often more as compared to the conventional surgery. However, operating time is likely to reduce significantly with more familiarity and decreasing learning curve. Another current limitation in micro-vascular field is that the presently available instruments are not yet small and fine enough to perform delicate micro-vascular surgeries like free flaps, micro-neurorrhaphy and digital replantations with finesse. (Rosson, 2005).

Although it is proved beyond doubt the advantages of Robotic micro-vascular surgery, persuading surgeons to use robots for microsurgery from microscope will not be easy. The appearance of Robot in the operation room definitely forces new skills upon the surgeon. Not all micro vascular surgeons perceive that robotic assisted micro vascular surgery is going to bring a significant change in the outcome. Though majority of surgeons agree that robotic micro-vascular surgery is feasible but puts a question mark over its superiority over the conventional methods both from technical aspect and cost-effectiveness.

9. The Future

RAMS in near future is likely to change the outcome in micro-surgical procedures by transcending the human limitations such as tremor filtration, dexterity and precision .With further advancement and refinement in areas of 3-D video imaging and display systems, tele-operative controls, tele-manipulators, graphic planners and micro-instruments, surgeon's capabilities will be tremendously increased with much improved surgical outcome. These advances will certainly make microsurgeries easier to perform and in the longer run will prove to be a dependable associate of plastic surgeons. The future of RAMS seems to be promising and continuing advancement of this technology holds the key.

10. Summary

Surgical robotic technology is now on the cusp of revolutionizing microsurgical capabilities. With the latest advancements in the field of RAMS, the armamentarium available to the plastic surgeons will be greatly expanded. The advantages are self evident. The use of RAMS technology during microsurgery will greatly improve the microsurgical outcome by providing surgeons with greater precision, elimination of hand tremors, increased range of motion and enhanced 3-D visualization. With the continued evolution of robotic surgical technology the robots are expected to become smaller, faster, lighter and dexterous with exponentially increased application in micro-vascular surgery.

The robots despite of technical advancements are never likely to replace the highly evolutionized human hand. The robots r ather than replacing the human hand will help to retain the benefits of the human hand along with its superlative optimization to achieve the goal of optimal precision and predictability. By combining the robotic technology with human skills, the RAMS system will allow the performance of more precise and more dexterous operations to the zenith. The present surgical training programmes must include some robotic training in their curriculum keeping in the mind its exploding potential and future use by the present and next generations of microsurgeons.

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Medical Robotics

Edited by Vanja Bozovic

ISBN 978-3-902613-18-9

Hard cover, 526 pages

Publisher I-Tech Education and Publishing

Published online 01, January, 2008

Published in print edition January, 2008

The first generation of surgical robots are already being installed in a number of operating rooms around the world. Robotics is being introduced to medicine because it allows for unprecedented control and precision of surgical instruments in minimally invasive procedures. So far, robots have been used to position an endoscope, perform gallbladder surgery and correct gastroesophogeal 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. The use of robotics in surgery will expand over the next decades without any doubt. Minimally Invasive Surgery (MIS) is a revolutionary approach in surgery. In MIS, the operation is performed with instruments and viewing equipment inserted into the body through small incisions created by the surgeon, in contrast to open surgery with large incisions. This minimizes surgical trauma and damage to healthy tissue, resulting in shorter patient recovery time. The aim of this book is to provide an overview of the state-of-art, to present new ideas, original results and practical experiences in this expanding area. Nevertheless, many chapters in the book concern advanced research on this growing area. The book provides critical analysis of clinical trials, assessment of the benefits and risks of the application of these technologies. This book is certainly a small sample of the research activity on Medical Robotics going on around the globe as you read it, but it surely covers a good deal of what has been done in the field recently, and as such it works as a valuable source for researchers interested in the involved subjects, whether they are currently "medical roboticists" or not.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Sanjay Saraf (2008). Robotic Assisted Microsurgery (RAMS): Application in Plastic Surgery, Medical Robotics, Vanja Bozovic (Ed.), ISBN: 978-3-902613-18-9, InTech, Available from:
http://www.intechopen.com/books/medical_robotics/robotic_assisted_microsurgery__rams___application_in_plastic_surgery

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