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# COMPETENCE, VIRTUAL REALITY AND ROBOTICS IN SURGERY

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## Summary

Surgical operations have developed in the method which the surgeon's hands and eyes are used to gain experience and advance the skills. However, to realize a new surgical therapy in the 21st century, it is necessary to use various advanced technologies. These include among many, three dimensional medical images, computer simulation and virtual reality technology, and robots in surgery. This is an outline of the various aspects of these technologies with some more details about robotics in surgery as it is the most recent advancement in that technology arena.

### Surgical Competence

Surgeons are under increased pressure to limit operative time and expense and to reduce patient recovery and inpatient hospital stay .In recent years, health payers, government , other non-medical groups, and the public have pressured hospitals and doctors to demonstrate that they deliver quality care .

For decades, professional postgraduate examinations and certification served as an icon for the qualifications of a surgeon to provide quality care. Candidates are expected to demonstrate high standards of education and training and attestation of ethical character to sit for these postgraduate examinations and gain certification[1]. Although this certification, which is a process regulated by the profession, indicates that the successful Diploma (fellowship) candidate has the training, knowledge, and skills to deliver quality care, it does not indicate that he or she actually delivers quality care[1] .

Competence has been defined as "the state of being sufficiently capable and properly qualified to do something at a level that is acceptable[2]. Incompetence is the "lack of ability or skill to do something successfully or as it should be done ". Due to the changes in patient expectations and the publication around the world of some high-profile cases with poor clinical outcome, both resulted in surgeons need to prove that they achieved and maintained surgical maintenance[3-5]. Professional bodies and boards, realize that a more comprehensive certification process is necessary for the public and health payers to endorse professional self-regulation in maters of quality of care and patient safety. The ultimate measure of performance in practice is the outcome of patient care. The concept of "maintenance of certification (MOC)"or recertification was therefore developed. After initial certification practicing surgeons will be required to demonstrate six general competencies on a continuous basis throughout their practicing lives[1] . In the case of American board certification, program directors and faculty of the accreditation council for Graduate Medical Education (ACGME) will also use these competencies to evaluate residency programs and residents[1]. These competencies were developed through a process that included broad societal representation, including the public, health payers, doctors, and many other groups. The competencies include : (1) core medical knowledge, (2) patient care with a compassionate attitude, (3) effective interpersonal and communication skills, (4) professionalism, (5) practice–based learning and improvement, and (6) systems-based practice including the ability to think and work under stress[1,2]. Maintenance of certification is based on participation and self–improvement not on sanctions or punishment. However, surgeons who fail to participate in the MOC program of their specialty will not maintain their certification. Surgical Colleges, Boards and their respective specialty societies are involved in providing and offering practice–specific education in many formats that provides recognized professional development programs. Surgeons are therefore regularly able to gain Continuous Medical Education (CME) awards and achieve Continuous Professional Development (CPD) credits. Although these programs might vary from one professional body to another, generally all share in their principles of an "Internal and External CME. Besides the ongoing, independent study, internal CME credits are gained through postgraduate meetings, research activities, journal clubs, and clinical audit (quality assurance, morbidity and mortality , and peer review). External CME awards are gained through external postgraduate meetings (presentations, symposia and conferences).external courses, visiting another unit, distance (online) learning and postgraduate examinations. keeping good records and documenting practical experience is useful for evaluating the surgeon's experience.

Virtual Reality "Learning by doing" has been the method through which surgeons in training have acquired their skill[6]. Over the past 15 years, advances in surgical instrumentation and electronics have transformed the practice of modern surgery and allowed for the rapid acceptance of minimally invasive techniques. Allowing residents to practice their skill directly on patients in the operating theatre has been the classroom for surgical training, but the cost of the operating theatre is ever increasing[7]. In the United States, it has been estimated that the annual costs to the healthcare system of operating theatre time alone for training of chief residents exceeds US$ 50 million per year[8]. After 1989, as Minimal Access surgery (MAS) became more commonly practiced, it became clear that the laparoscopic approach was associated with a significant higher rate of complication[9]. The underlying causes of these developments were complex but ultimately related to inadequate training of the skills necessary to overcome the psychomotor hurdles imposed by videoscopic interface. Concurrent with the growth of MAS, surgeons were already sensitive to the issues of medical error[3-5] and have accepted the idea that new and better evidence-based training is necessary and achievable[10]. Although surgeons defined more structured training methods, appliances and training Units The pattern remained on the same mentor-trance principle. At the onset of the 21st century, the surgical education establishment is searching for new and innovative training tools that match the sophistication of the new operative methods. Applications of real-time simulation for training involving computer modeling owe their existence of pioneering developments in the early and middle 1980s.These have already been incorporated into fields such as air and space fight large military and commercial vehicle control, mechanical systems maintenance, and nuclear power plant operations were procedures are regarded to be hazardous and mistakes are costly[11-13].

Virtual Reality (VR) is best described as a collection of technologies that allow people to interact efficiently with three dimensional (3D) computerized databases in real time using their natural senses and skills[14]. With the advancement of desktop computing power, practical and commercially available VR-based surgical simulators and trainers have been developed. These include simple simulators like venepuncture or more complex simulators for therapeutic gastroscopy, endoscopic retrograde cholangio-pancreaticography, and colonoscopic, procedures[14]. A radiological simulator provides training in cardiac catheterization and angiography, with real time modeling of physiological parameters and blood flow, and other simulators are also freely available[14], these VR simulators offer repeatable, logged computerized training, often without the need for supervision[15] .One of several commercially available procedural simulators is the 5DT Gastroscope Training simulator ( 5DT Inc, Santa Clara, CA ) It is a multimedia device designed to simulate the critical steps of a routine upper gastrointestinal tract ( GIT ) endoscopy[16]. A standard Gastroscope is fitted with a tracking sensor at its tip that is used to track the tip,s position and orientation, this information is fed into a standard PC ( PIII 650 MHz, 256 MB RAM, Geforce 256 – video card ) that hosts a 3D-computer graphics model to the GIT. As the instrumented gastroscope is inserted into a life – size transparent silicone rubber model of the oesophagus, stomach, and duodenum, the computer renders an image that corresponds to what would be seen when using a gastroscope in a real patient. The device provides a scorecard of the users performance, based on internal scoring of intimae such as percentage of total surface area viewed, time to complete the task, number of wall collisions, and number of injuries caused by the biopsy tool. The instructor has the ability to design different case scenarios. The validity testing of this device was studied and results reported by Bloom et al[16]. Thirty–five residents and fellows from General Surgery and Gastrointestinal Medicine were recruited for this study. The authors found that construct validation of this simulator was demonstrated. Performance on visualization and biopsy tasks varied directly with the subjects prior experience. The authors concluded that VR simulation might be a useful adjunct to traditional operating room experiences[16].

The Minimally Invasive Surgical Trainer Reality (MINST VR) system (Mesntice AB, Gothenburg, Sweden ) is another device that was used .It was found to be sensitive enough to distinguish between surgeons of different levels of experience in their psychomotor skills of speed of performance (completion time ), errors made, economy of instrument usage (path lengths), and economy of diathermy[17,18].

The MIST VR system (frameset v.1.2) was run on a desktop pc (400-Mhz Pentium II , 64 – MB RAM ) with tasks video subsystem employ ( matrix Mystique, 8-MB SDRAM ) delivered a frame rate of approximately 15 frames per second , permitting near – real time translation of instrument movements to the video screen. The laparoscopic interface input device ( Immersion Corporation , San Jose, CA ) consisted of two laparoscopic instruments at a comfortable surgical height relative to the operator, mounted in a frame by position – sensing gimbals that provided six degrees of freedom, as well as a foot pedal to activate simulated electro surgery instruments. With this system, a 3D box on the computer screen represents an accurately scaled operating space. Targets appear within the operating space according to the specific skill task selected and can be grasped and manipulated with virtual instruments. Each of the different tasks is recoded exactly as performed and can be accurately and reliably assessed[10]. In a randomized, double–blinded study Seymour et al[10] had baseline psychomotor abilities of 16 surgical residents assessed. The residents were then randomized to either VR training ( MIST VR simulator diathermy task ) until expert criterion levels established by experienced laparoscopists were achieved, or control non–VR trained . All subjects performed laparoscopic cholecystectomy with an attending surgeon blinded to the training status, they concluded that the use of VR surgical simulation to reach specific target criteria significantly improved the operating room performance of residents during that operation[10] .

In an another study[19], 21 medical students performing an initial VR case scenario ( pretest ) requiring rigid cystoscopy, flexible ureteroscopy with laser lithotripsy , and pasket retrieval of a proximal ureter stone . All students were evaluated with objective parameters assessed by the VR simulator and by two experienced evaluators using a global rating scale . Students were then randomized to a control group receiving no further training or training group, which received five supervised training sessions using the same case scenario ( posttest ) . The authors concluded that students trained on the VR simulator demonstrated statically significant improvement on repeat testing , but the control group showed no improvement. Using the same MIST VR system , the effect of sleep deprivation on the performance of simulated laparoscopic surgical skill was assessed[20]. Thirty five surgical residents were prospectively evaluated per-call (rested ), on-call (rested ), and post-call ( acutely deprived sleep ), the authors concluded that call – associated sleep deprivation and fatigue are associated with increased technical errors in the performance of simulated laparoscopic surgical, skills[20] .

The psychomotor skills were assessed in surgeons experienced in performing advanced laparoscopic procedures[21] . Two hundred ten surgeons attending the 2001 annual meeting of the American College of Surgeons in New Orleans whom reported having completed more than 50 laparoscopic procedures were participated in the study. Subjects were required to complete one box– trainer laparoscopic procedure and a similar VR task. These tasks were specially designed to test only psychomotor and not cognitive skills. Both tasks were completed twice. In spite of some limitations in that study[21] the authors concluded that objective assessment of laparoscopic psychomotor skills is now possible. Surgeons who had performed more than 50 laparoscopic procedures showed considerable variability in their performance on a simple laparoscopic and VR task . Approximately 10% of Surgeons tested performed the task significantly worse than the group’s average performance[21] .Studies such as this may form the methodology for establishing criteria levels and performance objectives in objective assessment of the technical, skills component of determining surgical competence .

Grantcharov et al[22] analyzed learning rate for laparoscopic skills on a VR training system and to establish whether the simulator was able to differentiate between surgeons with different laparoscopic experience. Forty one surgeons were divided into three groups according to their experience in laparoscopic surgery: masters (group 1, performed more than 100 cholecystectomies), intermediates (group 2, between 15 and 80 cholecystectomies), and beginners ( group 3, fewer than 10 cholecystectomies) were included in the study, the participants were tested on the ( MIST VR ) 10 consecutive times within a one month period. Assessment of laparoscopic skills included time, errors, and economy of hand movement, measured by the simulator, the authors concluded that different learning curves existed for surgeons with different laparoscopic background The familiarization rate on the simulator was proportional to the operative experience of the surgeons with experience surgeons demonstrated best and beginners the least[22] .

## ROBOTICS IN SURGERY

George kelling in 1901 was the first to examine the intra–abdominal cavity with an endoscope [23]. H.C. Jacobaeus in 1911 [23] reported the first large series of laparoscopic surgeries. After a long evolution and after the invention of the video chip or CCD ( charged coupling device) in mid 1980s the video laparoscope became possible and the first laparoscopic cholecystectomy was performed in 1987 [24] . At the Society of American Gastointestinal Endoscopic Surgeons (SAGES) in the 1989 annual meeting in Atlanta, Georgia Jacques Perrisat of Bordeaux , France presented his famous videotape on laparoscopic cholecystectomy [25] .

Open surgery afforded the surgeon a three-dimensional 3D view of the operative field, with the use of two hands permitting unrestricted and complete range of motion and movement, as well as the ability of continuously readjust body positioning to maintain a comfortable stance. At the same time, the surgeon was able to use many of his senses, including touch, smell, sight , and sound, to make decisions while operating. On the other hand, many studies have shown that laparoscopic procedures result in decreased hospital stays a quicker return to the workforce, decreased pain, better cosmetics, and better postoperative immune function [26, 27] .

However, even with the earliest reports of successful laparoscopic several limitations being identified. Some of the more prominent limitations involve the technical and mechanical nature of the equipment 26 . Inherent in current laparoscopic equipment is a loss of haptic feedback (force and tactile), natural hand–eye coordination, and dexterity. Moving the laparoscopic instruments while watching a two-dimensional video monitor is somewhat counter intuitive . One must move the instrument in the opposite direction from the desired target on the monitor to interact with the site of interest. Hand–eye coordination is therefore compromised. Some refer to this as the fulcrum effect [26, 28] . Current instruments have restricted degrees of motion, most have four degrees of motion, Whereas the human wrist and hand have seven degrees of motion. there is also a decreased sense of touch that makes tissue manipulation more heavily dependent on visualization. Finally, physiologic tremors in the surgeon are readily transmitted through the length of rigid instruments.

The motivation to develop surgical robots is rooted in the desire to overcome the limitation of current laparoscopic technologies and to expand the benefits of minimally invasive surgery [26,29] .

Since 1921 when Czech playwright Karwl Capek introduced the notion and coined the term robot in his play Rossom's Universal Robots, robots have taken on increasingly more importance both in imagination and reality [26,30,31] . Robot, taken from the Czech robota, meaning forced labour, has evolved in meaning from dumb machines that perform, repetitive tasks to the highly intelligent robots with advanced technology [26] .

Robotics, has been slow to enter the field of medicine, however currently it is fast expanding, the word is slightly misused in this connection. None of the systems under development involves a device that is acting autonomously. Instead, the system acts as a slave to the acts as a slave to the action of the master, the surgeon .

The United States (US) Army noticed the work of SRI, and hoped to develop a mechanism by which combat surgeons could operate from a remote secure location on wounded soldiers on the battlefield[34]. With the funding from the US Army, a system was devised whereby a wounded solider could be loaded into a vehicle with robotic surgical equipment and be operated on remotely by a surgeon at a nearby Mobile Advanced Surgical Hospital (MASH).

Several of the surgeons and engineers working on surgical robotic systems for the Army eventually formed commercial ventures that lead to the introduction of robotics to the civilian surgical community [26,30] .

There are two surgical tele-manipulating robots in various stages of FDA regulatory clearance that are being used to assist minimally invasive procedures for surgery :the "da vinci Robotic Surgical System"(Intuitive Surgical, Mountain View, California ) and the "ZEUS Robotic Surgical System " (Computer Motion, Goleta, California )[29,35].

The da Vinci surgical system, which is a master slave type of robot, consists of three main components. The surgeons sits at a surgeon's computer console. A cart encases the video and lighting equipment. A robotic tower supports the three (original system ) or four (newer system ) robotic arms [36] .

The computer console serves as the interface between the surgeon and surgical robot . the surgeon is the master and controls all actions of the slave robot. the surgeon views the operation through binoculars housed in the hood of the console. An infrared beam deactivates the robotic tower whenever the surgeon removes his eyes from the binoculars. the surgeon's arms are supported by a padded armrest. the surgeon's hands are inserted into freely moving masters, the masters convert the 3D motions of the surgeon's hands into computer commands that direct the robotic instruments to perform identical 3D movement [26,29,36] .

The endoscope is a specially designed 12-mm dual–camera telescope (thirty-degree and zero available) that is capable of sending a 3D image to a specialized viewing screen( binocular) in the console called the In site Vision System, which eliminate all peripheral images other than what is on the screen. By looking into this 3D system, the surgeon immerses himself into the operative field, the camera and instruments are both controlled by maneuvering the joysticks on the console. To alternate the digital handle's control back & forth between control of the camera & control of the instrument, the surgeon taps a foot pedal at the base of the console, there are now 18 different robotic instruments for the da vinci system that are appropriately called endowrist instruments, the unique design of the instrument tip literally recreates the same flexible movements of a human wrist[26,29,36]. In the near future, da Vinci systems will provide telescopes with three video cameras . the two 5–mm telescopes that provide stereoscopic imaging remain the same in these telescopes .An additional wide–angle lens with super video chip offers panoramic view of the operative field[36]

Once immersed in the da Vinci's virtual field, the surgeon inserts his fingers into the handles, sits in an ergonomically correct position, and then maneuvers the endowrist instruments with up to seven degrees freedom . these are in and out, elbow up & down, elbow left & right, wrist up & down wrist left & right, open & shut, & axial rotation . In effect, such maneuvering is like placing hands & wrists into cavities where they normally could never fit in, thus permitting the performance of delicate, precise dissection & suturing all through small skin incisions [26,29,36] .

The ZEUS Robotic System has two parts, the surgeon console & robotic instrument has arms connected by a computer interface that can filter tremor & adjust the movement & rotational scale of the instruments In contrast to the da Vinci, the ZEUS'S robotic arms are not on a cart, but instead can be attached directly to the operating room table. A second difference that the ZEUS uses a voice–activated camera control system that is called AESOP robotic endoscope positioner. Instead of requiring a special 12–mm endoscope as with the da Vinci, the ZEUS allows the use of routine 5 mm or 10–mm endoscopes with the AESOP arm. with this system, the surgeon could continuously commands like camera in or camera out. the third difference between the two robotic surgery systems is that the ZEUS system currently uses robotic laparoscopic instruments that mimic the hand-held laparoscopic instruments thus lacking the additional degrees of freedom that the surgeon will get with an endowrsits instruments tip design to mimic the human hand. However, with the rapidly advancing robotic technology the ZEUS system is already in its third phase of design and is now available with instruments called microwrist technology mimicking the movement of the human wrist [26 , 29 , 36] .

The learning curve associated with the introduction of a surgical robotic system into a surgeon's armamentarium was studied[37]. Twenty-three surgeon representing seven surgical subspecialties participated in a surgical robotics, training program consisting of standardized da Vinci system training ( phase 1 ) followed by self–guided learning in a porcine model (phase 2), the authors concluded that the mew use of the da Vinci robot is associated with a rapid learning curve & preclinical animal model training is effective in developing surgical robotics skill [37] .

Current Applications of Robotic Surgery **[26] :**

Orthopaedic surgery : Total hip arthroplasty: femur preparation , acetabular cup placement,. Knee surgery, Spine surgery .

Neurosurgery : Complement image–guided – surgery, Radiosurgery .

Gynaecologic surgery : Tubal re–anastomosis, Hysterectomies, & Ovary resection .

Cardiothoracic surgery: Mammary artery harvest, CABG, & Mitral valve repair .

Urology : Radical prostatectomy, Ureter repair, & Nephrectomy .

General surgery : Cholecystectomy, Nissen fundoplication, Heller myotomy, Gastric bypass, Adrenalecotomy, Bowel resection, Oesophagectomy .

### Telepresence surgery

Da Vinci was engineered from its inception to perform telepresence surgery [36]. To facilitate telepresence surgery, the computer console purposely isolates the surgeon from his environment, telepresence may offer technological solutions to the surgical manpower problems. Such as improving clinical outcomes for infrequently performed difficult operations or address the shortage of trained surgeons in remote geographic locations & deprived Countries [36]. Indeed, with the combined efforts led by Marescaux & his Strasbourg group & Gagner from Mount Sinai in New York, the first transatlantic robot-assisted cholecystectomy was performed in September of 2001 [38] .

### Comparison between robot-assisted surgery & conventional laparoscopic surgery

Advantages**:** laparoscopic surgery is well-developed affordable & proven efficacy technology. the robot-assisted system have their strength in: 3D visualization, improved dexterity, seven degree freedom, elimination of fulcrum effect, elimination of physiological tremor, ability to scale motion, micro–anastomosis possible, telesurgery & ergonomic position [26, 39].

Disadvantages**:** In laparoscopic surgery there is loss of touch sensation, loss of 3D visualization, compromised dexterity, limited degrees of motion, the fulcrum effect, & amplification of physiological tremors. In the robot-assisted surgery there is absence of touch sensation, very expensive technology, high start-up cost may require extra staff to operate, new technology & so far has an unproven benefit [26,28,39] .

### Comparison between robot– assisted surgery & conventional surgery

Human strengths **:** Strong hand–eye coordination, dexterous, flexible & adaptable, can integrate extensive & diverse information, haptic feedback, use qualitative information, able to make good judgment & easy to instruct & debrief [26] .

Human limitation**:** limited dexterity outside natural scale, prone to tremor & fatigue, limited geometric accuracy, limited to use quantitative information, limited sterility, & susceptible to radiation & infection [26] .

Robot strengths**:** good geometric accuracy, stable & untiring, scale motion , use diverse sensors in control may be sterilized & resistant to radiation & infection [26] .

Robot limitations**:** No judgment, unable to use qualitative information, absence of haptic sensation,expensive, technology advancing & changing & more studies are needed [26] .

There are several disadvantages to these robotic system[26]. As a new technology more studies for long follow up are needed & many procedures need to be redesigned to optimize the use of robotic arms . the cost is one million US dollar for each system . However, some believe that with improvement in technology & as more experience is gained , the price will fell [39] . While others believe that improvement of technology will raise their costs[28] . Upgrading these systems & how often to upgrade is also an important issue . It is believed that to justify the purchase of these systems they must gain widespread multi-disciplinary use[28] , the size of these system is another disadvantage, the solution for that is either miniaturizing the robotic arms & instruments or developing larger operating rooms, each of these will create more changes & advances[26] .

The future of robotic surgery

Although some in the surgical community continue to test the feasibility of robotic surgery & to question the necessity of such an expensive venture, others are already postulation how to improve the next generation of telemanipulators[29] the enthusiastic adoption & use of the da Vinci in over 150 medical centers in the USA suggests that telerobotic control of laparoscopic instruments does provide significant clinical value[36]. The ultimate utility of robot in surgery can and will extend far beyond current capabilities[36]. Many obstacles and disadvantages will be resolved in time and no doubt many other questions will arise[26].

Much like the robots in popular culture, the future of robotics in surgery is limited only by imagination[26]. Satava[25] though that the future is not with systems as they exist today as already new concepts that DARPA (Defense Advanced Research Projects Agency) is funding. In the future, the patient will be bought to the preoperative holding area and placed upon a smart stretcher that records the vital signs & all other physiologic & biochemical parameters about the patient, who will then be anaesthetized. A total body scan is performed & the patient is then completely prepped for sterility. During that time, the surgeon can warm up on simulators. Or the surgeon can be sitting at the surgical console with the preoperative scan, rehearsing the procedure on the patient's image then edit the procedure until it is exactly as the surgeon would like it to be performed. Alternatively, the surgeon can finally execute the operate command to have an errorless operation while the surgeon supervises the performance of the robotic procedure[25] . In the operating room there are no people. Instead of the scrub & circulating nurses, the surgeon will be able to control numerous hands, the instruments are changed automatically, & the supplies (like sutures ) are automatically dispensed .

Furthermore the surgical instrument will move more toward energy–directed systems. In addition, some systems will begin surgery at the microscope & cellular level a concept termed biosurgery[25,40] the goal of surgery will be to change the function rather than the structure of the organ or disease .

Finally the robotic system, coupled with sophisticated decisions–support systems, will be able to monitor (record) the surgeon performance in real time & act as mentor to suggest alternatives or alert the surgeon when there is a deviation from a normal action [25] .

Such speculations are based on the current technologies & their progress. It is expected that many questions will arise, such as training requirements, credentialing, licensing & malpractice liability[26] . One issue that may arise if there will be a disagreement on an action or a decision between the judgment of the surgeon & the alternative suggested by the robot, should the surgeon , s choice prevail & if an adverse outcome results, is the surgeon or robot at fault [25] .

Let use wait for the future to see what is going to bring .

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