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Evolution Of Robotic Surgery And The Need For Robotic Endotrainer

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Abstract - One of the key areas of Medical Robotics is the development of Surgical Robots for minimally invasive surgery. The use of robotics in surgery is now broad-based across multiple surgical specialities in the world and will undoubtedly expand over the next decade in developing countries as new technical innovations and techniques increase the applicability of its use. Since the role of surgical robots is graphically increasing, the need for its training plays a vital role and the best possible approach is by using robotic endotrainers. There are 60 surgical robots and 360 qualified physicians across 20 cities in India using da Vinci robotic systems. As surgical robots are on the floor now, there is a need for the actual robot based surgical training systems for better utilization of the surgical robots. This review paper focuses on the evolution of robotic surgery and the need for robotic endotrainer in the developing countries like India to train medical professionals in the field of minimally invasive robotic surgery.

Keywords: Robotic Surgery, Robotic Endotrainer, Medical application, Technology evolution, Economic benefits

1. INTRODUCTION

It had been five decades since Isaac Asimov invented the eminent three laws of robotics - a set of laws aimed to certify cordial robot attitude [1]. Technology is inching closer to the day where there will be robots everywhere, or more precisely, the dawn of Artificial Intelligence that runs them that are adaptable and flexible enough to pick out distinct courses of behavior. Certainly, it will only be a matter of time before machine intelligence breaks out ahead of human capacities in all the ways imaginable, counting power, speed, and even physical reach.

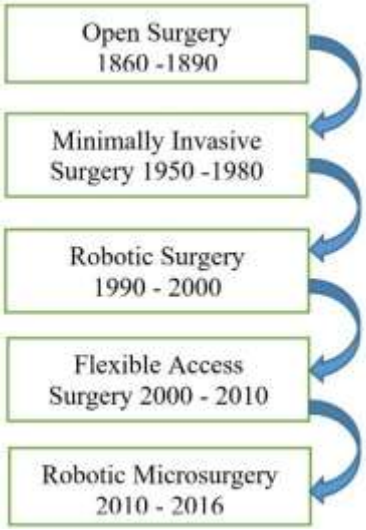

Fig.1 Timeline of surgical technology development

Robotic technology is entering the mainstream health care system, and surgical robotics is an emergent technology, which is getting to the medical field in force and creating waves in India. It is an evolution in the field of robotics. Fig.1 shows the timeline representation of surgical technology from 1860 to 2016. Open surgery, antiseptic and image-guided surgery were performed in-between 1860-1890. Angioplasty, fiber-optic flexible endoscope, laparoscopy were introduced during 1950- 1980. Next, the robots took the surgical procedure to a level forward. The da Vinci® surgical system, Transcontinental robotic telesurgery, Sensei™ Robotic catheter system were all performed from 1990-2000 [2].

Flexible access surgery performed during the following ten years i.e. 2000-2010. Micro-robots explored to a flexible platform for microsurgery from 2010 to recent times. Elastic snake-like and micro-robotic platforms are developing and expected to further expand the surgical outcomes and blur the boundaries between prevention and intervention. From its beginning, with the introduction of ancestral robots like the PUMA, PROBOT, and ROBODOC to the present state-of-the- art da Vinci Xi surgical system, robotic surgery has come a long way. The da Vinci robot confirmed to be one of the best surgical robot used for appropriate and clear-cut surgical operations. The justification behind the unprecedented explosion in the use of robotics lies in the inherent advantages of robotic surgery over conventional laparoscopic surgery which include superior ergonomics, enhanced magnification, 3D-vision, motion scaling, tremor filtering, enhanced dexterity, precision and control of operating instruments. From the patients' perspective, this translates to smaller incisions; minimum pain; low damage to healthy tissue; minimal blood loss during surgery; less visible scars; reduced risk of wound infection; less time in the intensive care unit; reduced hospital stay along with faster recovery time. Speedy dissemination of the technology and technique together with aggressive marketing has captured the imagination of the doctors and patients alike.

Robotic Endotrainer allows the physician to perform successful surgery for the patients with minimal prior real-time laparoscopic experience. It compromises the outcome of experienced physician in ordinary laparoscopic surgery. For the laparoscopically trained physician, it enables operating with greater precision and accuracy. Learning this naive medical technology requires guided and self-directed training. Therefore, in focus to develop the knowledge and skills to use the surgical robots safely and efficiently the need for design and development of a robotic Endotrainer is significant. This paper runs through the evolution of robotic surgeries and the call for robotic endotrainer in India.

Ascent of Robotic Surgery

Among the surgical fraternity, urologists were one of the earliest to realize the immense potential of Robotic surgery. Robotic Surgery has kick-started a standard shift in the fundamental foundations of surgery. The increasing popularity of robot-assisted surgery has caught up in Europe, Asia, Australia, USA, and spread to specialties like cardiothoracic surgery, gynecology, otorhinolaryngology, surgical oncology, gastrointestinal surgery, bariatric surgery and general surgery. In olden days, the practice of surgery was more of a technical craft whereas modern surgery is now strengthened by technology in many allied fields involving anesthesiology, radiology, microbiology, histopathology, immunology, and oncology among others; covering a wide spectrum of medical procedures [3].

The major advances aided by surgical robots have been remote surgery, and minimally invasive surgery. In developing countries like India, robotic surgery is still in its infanthood. Currently, there are just 360 Robotic physicians across 20 cities in India using surgical robots [4]. The All India Institute of Medical Sciences (AIIMS) has been at the forefront of the robotic revolution in India [5]. In 1985, PUMA 560 Computerized Tomography-guided brain biopsy was the initial documented adoption of a robot-assisted surgical procedure. Minimally invasive surgery began in 1987 with the first laparoscopic cholecystectomy. In 1998, a computer integrated prostatectomy system called the PROBOT was brought in the medical field. A Robotic assistant named the ROBODOC for total hip arthroplasty was introduced in 1992. To help the physicians, ZEUS surgical system was popularized in 1994. In 2000, the da Vinci Surgery System broke the ground by becoming the first Robotic surgery system approved by the Food and Drug Administration for general laparoscopic surgery. In India, the first Robotic radical prostatectomy was performed in A.I.I.M.S. New Delhi in July 2006. In 2007, the artificially intelligent companions moved closer to replace the physicians and benefit the patients by improving the healthcare systems. In 2008 promises continued advancement in the zonal of artificial intelligence, to reach the point where Robots will be heading their role in the medical field. In 2009-10, there were only five or six physicians trained to carry out Robotic surgeries in a country like India and by 2013, 2600 Robotic procedures were performed. In the following year, the count was increased by 200. Later in 2015, a total of 26 da Vinci systems were in operation in India with 147 trained physicians in Robotic surgeries at various hospitals and 4000 Robotic procedures were performed. This shows an obvious hike in the number of robotic procedures [5]. Subsequently, it started spreading across different specialties of surgeries. There are three surgical Robots that have been developed and they are Da Vinci surgical system, ZEUS Robotic surgical system, AESOP Robotic system. So as the result of technology development, people are now quite aware of the evolution of Robotic surgery and are expecting and welcoming Robotic surgeries in developing countries.

Robotic Surgery

The field of surgery is entering a time of great change, spurred on by remarkable recent advances in surgical and computer technology. Recently Robotic systems made their way into the operating room as dexterity enhancing surgical assistants and surgical planners as an answer to physicians' demands for ways to overcome the surgical limitations of minimally invasive laparoscopic surgery. Robotic or Robot- assisted surgery integrates advanced computer knowledge with the experience of the skilled physicians. This technology provides the physician with a 10x magnified, high- definition and 3D-image of the body's intricate anatomy. The physician uses controls in the console to manipulate special surgical instruments that are smaller, as well as more flexible and as of now instruments can be more flexible but not more maneuverable than human hand. Robot-assisted minimally invasive surgery can knock out physical tremor, introduce scaling factors between the hand motions of the physician and the robotic instruments, and provide additional articulated joints at the tips of the instruments. The Robot replicates the physician's hand movements while minimizing hand tremors. The physician thus can operate with enhanced precision, dexterity, and control even during the most complex procedures. Fig.2 shows the different aspects and review of robotic surgery system faced by a robotic Institute, which includes the benefits to the patients, the types of surgical system available, advantages and the usage of robotic surgery system in the various medical fields. Most training models are divided into two categories, system training, and procedural training, and their guidelines contain means to train knowledge and skills for the specific category. System training refers to knowledge and skills that are specific to the robotic system used; procedural training refers to the knowledge and skills needed to perform specific procedures with the robotic system. With a stepwise and systematic training, a safe and efficient use of the robotic surgery is possible. Artificial Intelligence will enable robots to be spatially aware; understand and respond to complex commands and environments in future surgeries; whereas remote control, voice activation and defined work volume with haptic feedback are the methods by which these surgical robots are controlled.

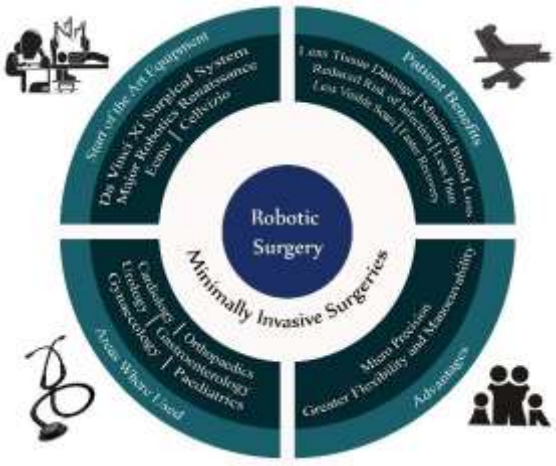

Fig. 2 Aspects and review of robotic surgery faced by a robotic Institute

Robotics is being introduced to medicine because they allow unprecedented control and precision of surgical instruments in minimally invasive procedures. The ultimate goal of the robotic surgical field is to design a robot that can be used to perform closed-chest, beating heart surgery. The most significant advantage to robotic surgery to the patient is the

decrease in pain and scarring. The smallness of the incisions also causes many other advantages that make robotic surgery worth the risk. Besides the obvious rewards to the patient, robotic surgery is also very advantageous to the physician and hospital. The first generation of surgical robots are already being installed in a number of operating rooms around the world. These are not true autonomous robots that can perform surgical tasks on their own, but they are lending a mechanical helping hand to physicians. These machines still require a human physician to operate them and input instructions. According to one manufacturer, robotic devices could be used in more than 3.5 million medical procedures per year in the United States alone.

Design and Architecture

In robotic surgery, medical robots require specific safety measures, kinematics, hardware and software to perform the medical procedures. Fig. 3 shows the flowchart of the surgical robot. The design architecture comprises of master side and slave side. The physician operates a master tool manipulator (MTM) having seven active joints plus one passive gripper with Hall effect sensors. In normal laparoscopic surgery the degrees of freedom is restricted while in surgical robots the degrees of freedom is seven.

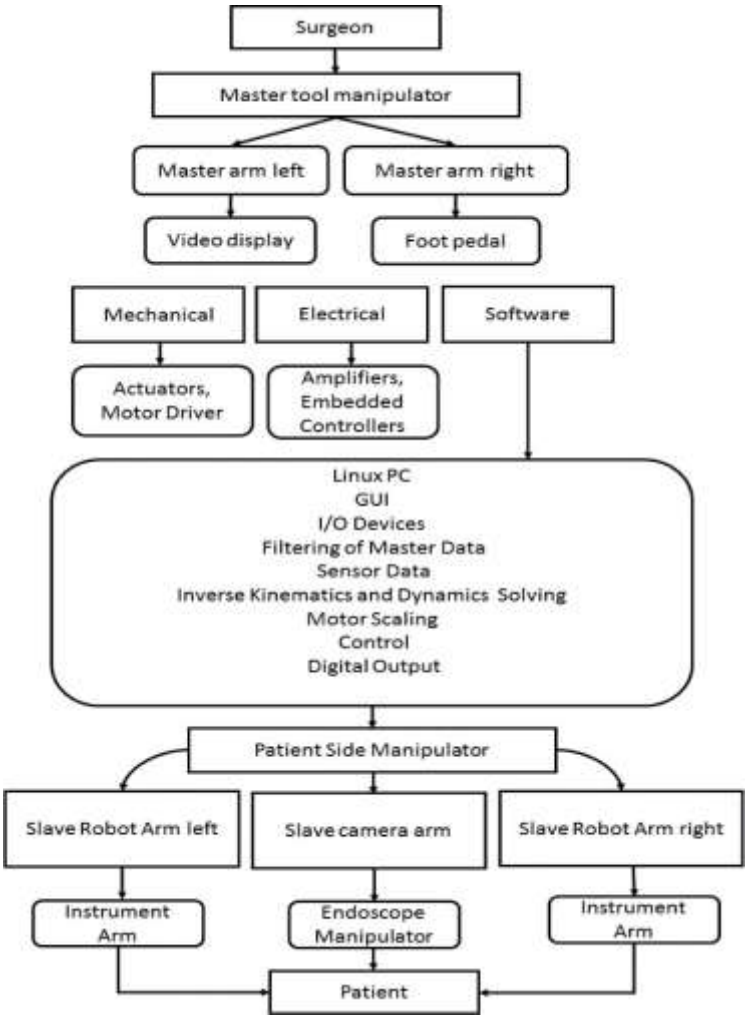

Fig.3 Surgical robot flowchart

The patient side manipulator (PSM) also has seven active joints driven by seven actuators. Through an adapter, a variety of instruments, such as forceps and scissors can be installed onto the patient side manipulator to perform different tasks during surgery. The surgery is performed using very small tools attached to a robotic arm. The instrument is driven by the last four actuators with a cable- driven mechanism. By use of foot pedal switch the control of one of master left/right will be transferred to control endoscope manipulator. The system architecture provides the advantages of reduced cabling, and allow all software to be implemented on a high-performance computer that contains a familiar software development environment. The physician who has to perform surgery controls the robotic arm with a computer. All computation including data read/write, servo loop control and high-level robot control can be implemented on a Linux PC. A low-level C++ library is required to allow direct access to the raw I/O data. This will be used in master side manipulator and patient side manipulator for handling forward kinematics, inverse kinematics, trajectory generation, robot-specific control (e.g. gripper open angle) and most important high-level robot state control.

Drawbacks, Expected Risk and Mitigation from Technical Experts

The availability of actuators, absolute encoders, harmonic drive and the like are very low in the market and in developing countries the market growth is below average when compared to other developed countries in manufacturing the components that are required for developing the surgical robot. All these components are available in the international market and we could buy from them. However, the main drawback is the shipping duration that will take about three to four months. The problem does not end with shipping alone. There are few other problems like service and maintenance. When there is a problem with the surgical robot, the technician has to come in order to do the service. This will involve significant time and expense. Components like incremental encoder is available in the market. However, problems can occur during surgery when there is a power shutdown in the course of surgery, there will be a loss in memory and the physician has to move the arm to home position and continue the surgery. The instruments used by the surgical robots have to be replaced strictly and the arm along with the instrument has to be taken care of and maintained in a proper way.

Utilization of Robotic Surgery

There is always something special about robots as they are signing their presence in diverse fields. Among that, medical robotics is at the bottom of a shift in therapy. Numerous physicians and engineers who worked on surgical robotic systems for the army eventually formed commercial ventures that lead to the introduction of robotics to the civilian surgical community. The instant surge in medical robotics is driven by a fusion of technological improvements [6]. The boost of surgical robots is encouraged basically by the greed to augment the effectiveness of a procedure by coupling information to accomplishment in the operating room or interventional suite [7]. Urological procedures that have been implemented with robotic assistance include extirpative oncological surgeries like radical prostatechomy, radical cystectomy, anterior pelvic exenteration, radical nephrectomy, partial nephrectomy, adrenalectomy and lymph node dissection. Most of the reconstructive surgeries like pelvic pyeloplasty, vesicovaginal and ureterovaginal fistulae repairs are being performed. Other specialities have now hopped on to the robotic bandwagon. Using the robotic system, gynecologists are now performing radical hysterectomies and myomectomies. ENT physicians are performing robot-assisted surgery in the nasopharynx and oro/hypopharynx for benign and malignant lesions to achieve better

functional results compared to traditional open surgery. Different kinds of gastrointestinal procedures are being performed with robotic assistance. These include colorectal surgeries, esophageal fundoplication, pancreaticoduodenal procedures and bariatric surgeries. There are still more many applications like cardiac surgery, gastrointestinal surgery, gynecology, neurosurgery, orthopedics, pediatrics and so on.

It is evident that, the significant use and application of robotics in surgical interventions is at its hike. The ultimate goal of the robotic Endotrainer will be training a surgical team with an Endotrainer and provide opportunities for the physicians to safely and efficiently integrate the technology into clinical applications while using the surgical robots. Robotic surgery is providing the technology to address many inadequacies and allowing the application of minimally invasive surgery to a broader spectrum. It is also rightful to estimate that the current advantages of robotic surgery systems will be enlarged upon the next propagation of medical robotics [8].

Economic Challenges

A major reason why robotic surgery in India has not progressed at a rapid rate is the financial factor. The new Da Vinci Xi launched in April 2013 currently sells for $1.2 Million. The annual maintenance costs along with the disposables supply cost $5000 per procedure which make it beyond the reach of many institutions and health care systems in developing countries [9]. The only way to tackle this and to make robotic surgery financially feasible is by multidisciplinary utilization of the robotic system to its fullest potential. The maintenance costs remain the same independent of the number of cases done in a day. So it is logical that if more cases were generated out of a robotic system; the cost per case would automatically decrease. Government support is also of paramount significance to help in dissemination of robotic technology, so that it becomes available to the common person at a subsidized rate. The media also has an important role to play in spreading awareness among the public about this new technology. Similarly, the primary care physicians need to be made aware so that they can refer the cases to the robotic centers.

Another alternative feasible way to reduce costs would be to develop indigenous surgical robots within the country. This will reduce the transportation cost, and time; reduce cost to a large extent in system service as well as maintenance aspects which will take time and consume a lot of money. In this aspect, a grant was awarded by the Global Innovation and Technology Alliance (GITA); Department of Science and Technology (DST) Government of India for a joint industrial research and development project on the design and development of robotic endotrainer under the India-Republic of Korea joint applied programme. The Department of Urology, PSG Institute of Medical Sciences and Research mooted the idea to explore the development of a robotic endotrainer to be designed along with the Department of Robotics and Automation Engineering at the PSG College of Technology and Korea Advanced Institute of Science and Technology, Daejeon. As academic partners focusing on medical robot-aided for surgery, Larsen and Toubro Technology Services is also working as an industrial partner in this project. Now with this tie-up, they are having some headway with the goal of evolving a cost-effective robotic endotrainer, in selected frontier areas of medical robotics to support the development of the endotrainer as well as to emerge as a research group of international repute.

One major drawback with the current Indian scenario is the lack of robotic surgery fellowships in India. Young Indian urologists wishing to specialize in robotic surgery need to go abroad to get trained in the nuances of robotic surgery. How many of these physicians do actually come back after their training is a question. So robotic surgery fellowships are

the need of the hour at present if professionals wish to take robotic surgery to the next level in India. Despite many technological leaps, methodology of surgical training has stayed more or less unchanged since inception. Physicians in training have always had to gain operative experience through "supervised trial" on real patients' [10]. This approach makes surgical training completely dependent on the actual caseload; prolongs surgical training, and compromises patients' safety. Hence robot based surgical training is required; and to justify this an Endotrainer is expected by the medical professionals. Training the doctors with da Vinci robotic surgery system is quite expensive which costs around 4500 USD per week.

Mimic technology is offering courses at hospitals and call for fellowship programs worldwide. Doctors around the world who wish to take training for robotic surgery can look for such fellowship programs and get free training. A few hospitals bought the surgical trainer from mimic technology as hospitals felt that training on da Vinci robot is expensive and mimic technology is economical. Similar to this many robotic endotrainers are needed for training the physicians. Robotic endotrainer is creating a new medium for an acquisition of surgical skills through simulation of all operations that can be done via the robot.

Intellectual Property

Surgical robot represents one of the best surgical innovation and they are improving surgical outcomes for patients. They can assist physicians but not supplant them. One imperative aspect to deliberate when conferring Intellectual Property (IP) rights is the prosperity of industrial patents that are unrealized or unrealizable. The patents cape is gently morphing into a collection of proposed systems and mechanisms that are not intended for realization. This dilutes the meaning of "invention protection", and poses risks to future businesses by essentially making a "patent minefield" that may hinder capitalization of innovation. Vigorous patenting appear like a prerequisite for fruitful commercialization. Da Vinci's parent company owns or has exclusive rights to 1800 patents, with another 1500 pending, and adds roughly 100 to 150 new patent applications and patents each year [11]. Patent protections are critical to Intuitive surgical's success. Intuitive continues to introduce significant technological advancement in areas like diagnostics and enhanced imaging furthering theimportance of intellectual property in medical robotics. In the Indian market, developers are in the starting stage of surgical robots and endotrainers.

As discussed above, surgery by robot is an emerging field; many countries had developed their robots and are continuously getting the patent for their own concepts. A drastic increase in getting patency shows huge market and competition behind the surgical robots. Therefore, it is the right time to design and develop both surgical robot and endotrainer in India.

Ethical Issues and Keys

With the rapid introduction of revolutionary technologies in surgical practice, such as computer-enhanced robotic surgery, the complexity in various aspects, including medical, legal and ethical, will increase exponentially. There are few important legal and ethical implications emerging from the application of robotic surgery. To say a few; time lag between physicians' commands and action of robot could harm the patient; loss of power during an electric failure may cause problems. Simulation-based practice will be more beneficial but still, it is restricted to use only the standard in-built programmed surgeries

and there is a lack of real surgery feel for the physicians.

Role Play of Endotrainers

Endotrainers are the excellent aid to training in laparoscopy and it allows trainees to practice the various surgical procedures without the pressures of the operating room [12]. It permits the repetitive performance of a single task; and to allow the trainee to develop hand-eye coordination and motor skills before entering the real-patient setting. The learning curve for any robotic laparoscopic procedure becomes smooth and quicker with endotrainer. The Endotrainers are not only useful for skilled and proficient physicians, it is also useful for the medical students and research scholars in the medical field and shows splendid outcome. There is a need to train general physicians and laparoscopic physicians outside operation theaters. This method of learning is cost-effective, ensure patient safety and devoid of complications. Affordable, homemade, inexpensive endotrainers are available for practice. For laparoscopic training audio-visual seminars are be arranged during periods of training. This training module can be employed not only by urban hospitals but also by rural hospitals to improve the skills of endo-surgery [13]. Individual hospitals, which have the interest for different areas of trainings in laparoscopic surgery can train their physicians on Endotrainers before operating real patients [14]. The robotic surgery has been rapidly accepted and implemented by a majority of the physicians.

In recent years, simulation has been using for teaching technical skills to surgical trainees. In developed countries, there is a paradigm shift towards the use of simulation-based training. There are some limitations like decrease in work hours for residents in laparoscopic theaters, short training programs, a decrease in available operating-room time, and legal issues of patients. In future, trainees will learn all basic and advanced skills in a supervised training environment. Simulations are safe for practice with minimal chances of error. They provide good opportunities for learning in order to standardize the experience for trainees. A large variety of models is currently available for training. These models range from high-fidelity animal or cadaveric models to virtual-reality simulators [2].

Fig.4 depicts the block diagram of a general robotic Endotrainer. It comprises of two phases. The first phase is the minimally invasive surgical robot Endotrainer, on which the physician's console will have two robotic arms where the physician manipulates according to his procedure. These are the master arms. The slave arms will move according to the motion produced by the master arms. The first robot will have the Master arms and the simulator, and in the second phase, the slave system with 3D Vision cameras will be developed. One of the slave arm will be the camera arm that will provide the physician a closer view of the operating environment. The physician can control any of the slave arms using the master arm and be able to select the control using selector switches or touch screen. The master and slave arms are electrically isolated so that the arm movements can be scaled to the precision required by the user. Encoders will read the movement of the Master arms and then a computer will send the corresponding commands to the slave arms for operating. Since the arms are electrically isolated, the motions can be scaled according to the physicians wish. Introducing the robotic endotrainer kits in clinical training will be useful for the physicians to check the time lag problem, perform microsurgeries or critical surgeries on fresh cadaver or anesthetized animals. This also leads to research in other open or laparoscopic surgery done by physicians. It will be a challenging task and good practice as it can be seen as a trial and error method. Static balancing by gravity compensation and use of uninterrupted power supply overcomes the electric failure problem. The surgeries that are not possible to get trained via simulation are overcome using the real-time robotic endotrainer and the

doctors can validatetheir performance level too.

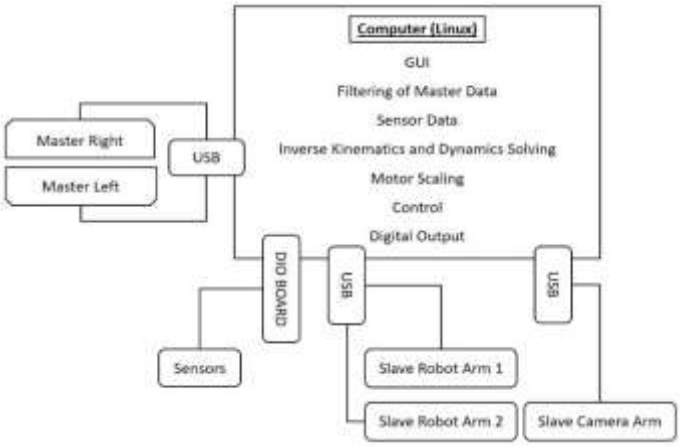

Fig.4. Endotrainer block diagram

Roadmap for the Future

Surgical robotics is acknowledged worldwide as a technological field primed for investment, where chief breakthroughs are awaited [2]. Robotic surgery is more scientific in handling with surgical parameters. Like the robots, the future of robotics in surgery is limited only by imagination. It is evident to see how smart the robots are powered by Artificial Intelligence replacing the human nowadays. Modern advancement encompasses the fusion of the TileProTM multi- image stereo viewer which facilitate simultaneous display of multiple video inputs in the physician console; integrating patient's ultrasound, computed tomography, and Magnetic Resonance Imaging; incorporation of haptic feedback together and wireless technology. Newer robotic surgical platforms like miniature robotics and flexible robotics are on the horizon. Hence robots are not just seen as machines, but they are also actually more accurate than human beings with an information system in their arms. Many more medical robots are presently being researched [15]. RAVEN and MiroSurge are the two prominent academic robot-assisted surgical systems that are currently used for research into endoscopic telesurgery [6]. Such research will lead to the new capabilities of future commercial systems.

Robotic surgeries in developing countries like India are here to stay and it is up to physicians and robotic engineers to lead the way and make the utmost gain of robotic surgery and this means surgery is about to get even more engaging. India now stands at the cusp of a robotic revolution. The future of robotic surgery is a successful challenge and road ahead to evolution which is near as promising as the human will invent superior ways of attaining delicate medical conduct [8]. By 2022, more than 100 hospitals across 25 Indian cities are expected to get Dexterous Robots with a 3-D vision to assist in medical surgeries.

2. CONCLUSIONS

The Digital platforms have the power to interact with other information systems such as imaging from computed tomography to allow the augmented reality of the surgical field. The efforts has lead to a multitude of academic centers and research institutions undertaking research in the field of surgical robotics. The percentage of the discovery of new technology is outpacing the competence of business, society, and healthcare to assimilate and apply. All these points lead to a conclusion that robotic surgery will be the standard minimally invasive

surgical technique. Improvements in medical robotics is addressing and solving real problems in healthcare, ultimately providing a clear improvement in the quality of life when compared with the alternatives. India is expecting to have robotic endotrainers in maximum number of hospitals, medical research places that will more or less depict an actual surgical robot exclusively used for training with a cost-effective solution for the surgical community. It is not far from now for us to see the benefits of robotic endotrainer that will be helpful to utilize the real surgical robot like da Vinci Xi surgical system, ZEUS robotic surgical system, AESOP robotic system etc. This Endotrainer will make robotic surgery easier to learn; get greater control over surgery to operate; cost-efficiency; accuracy as in formerly available robotic surgical units; less invasive; precise surgical procedure; controlling various tasks along with real-time hands-on surgical training for the physicians; medical students in hospitals; research institutions and colleges which in turn will bring a revolution across India.

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4. REFERENCES

[1] S.L. Anderson, "Asimov's three laws of robotics and machine metaethics," AI and Society, vol. 22, no. 4, 2008, pp. 477–493

[2] "Surgical Robotics: The Next 25 Years Successes, Challenges, and the Road Ahead", 2016. Retrieved from http://hamlyn.doc.ic.ac.uk/ukras/sites/ default/files/UK_RAS_WP_SR25yr_web.pdf

[3] Vitiello V, Lee SL, Cundy TP, Yang GZet al., 2013, Emerging robotic platforms for minimally invasive surgery., IEEE Rev Biomed Eng., Vol: 6, Pages: 111-126

[4] The Hindu Business Line (2018, January 15). Retrieved from https://www.thehindubusinessline.com/business-wire/da-vinci-surgical- robot-to-be-a-star-attraction-for-aicog-2018- attendees/article10033022.ece

[5] Dr. (Prof). Arvind Kumar. (2016, February 18). Retrieved from http://blog.drarvindkumar.com/future-of-robotic-surgery-in-india/

[6] Ryan A. Beasley, "Medical robots: current systems and research directions," in Journal of Robotics, Volume 2012, Article ID 401613

[7] Peter Kazanzides, Gabor Fichtinger, Gregory D. Hager, Allison M. Okamura, Louis L. Whitcomb, Russell H. Taylor, "Surgical and interventional robotics - core concepts, technology, and design" IEEE Robotics & Automation Magazine, Volume:15 , Issue:2, June 2008

[8] History and the future of robotic surgery, retrieved from https://www.roboticoncology.com/history-of-robotic-surgery/

[9] Qmed (2017, March 31), retrieved from http://www.qmed.com/mpmn/ medtechpulse/can-newest-da-vinci-robot-smash-cost-barriers

[10] Gomez G, "Emerging technology in surgery: informatics, electronics, robotics," Sabiston textbook of surgery. 17th ed. Philadelphia, PA: Elsevier Saunders; 2004

[11] Tim Sparapani (2015, June 19), retrieved from https://www.forbes.com/sites/timsparapani/2015/06/19/surgical-robotics-and-the-attack-of-patent- trolls/#1ce898f1389f

[12] Dunkin B, Adrales GL, Apelgren K, Mellinger JD, "Surgical simulation: a current review," Surg Endosc. 2007; 21: 357-366

[13] Hammoud MM, Nuthalapaty FS, Goepfert AR, "To the point: medical education review of the role of simulators in surgical training," Am J Obstet Gynecol. 2008; 199: 338-343

[14] Dent TL, "Training, credentialling, and granting of clinical privileges for laparoscopic general surgery," Am J Surg. 1991 Mar; 161(3): 399-403 [15]Paula Gomes, "Surgical robotics: Reviewing the past, analysing the present, imagining the future," Robotics and Computer-Integrated Manufacturing, Volume 27, Issue 2, April 2011, Pages 261-266

[15] Ismail, M. N. B., Sayed Hussin, S. A. B. and Shukran, M. A. "Gesture Recognition Robot Via Kinect Sensor", IARS' International Research Journal. Vic. Australia, 6(1) 2016. doi: 10.51611/iars.irj.v6i1.2016.54.