Review Article

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Robot-assisted Laparoscopy Surgery

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Abstract

A robot is a computer-controlled device that can be programmed to aid the positioning and manipulation of surgical instruments also. The goal of robotic surgery is to use a minimally invasive approach to perform procedures which are generally performed by laparotomy or are too complex for routine laparoscopy. There are certain advantages of robotic over conventional laparoscopy which include better imaging, mechanical improvement, stabilization of instruments within the surgical field, and improved ergonomics. The major advantage to the patient is a potentially shorter hospital stay, and more rapid postoperative recovery and return to full function. The limitations of robotic technology include high costs, increased operating room time due to large size of the devices and need for training. Surgical simulation, telementoring, and telepresence surgery are potential novel benefits of robotic technology. Further evaluation and implementation will determine the role of robot-assisted laparoscopy.

Keywords: Robotic Surgery; Minimal Invasive Surgery; Minimal Access Surgery; Robot Assisted Surgery.

Introduction

A robot is a computer-controlled device, which can be programmed for manipulation of surgical instruments which is generally used in minimal access surgery. After the introduction of laparoscopy, few limitations were felt by the surgeons like 2D vision, ergonomic limitations and difficult articulation in manipulation of instruments specially in prolonged surgeries. Robot-assisted laparoscopic surgery helps in overcoming these limitations, and hence improves patient care. It has all the benefits of minimal access surgery like smaller incision, less post pain, less hospital stay and early return to work.

United States-Food and Drug Administration [US FDA] has approved Da Vinci Robotic system for use in surgical procedures in 2000 and in gynecologic surgery in 2008 [1]. Da Vinci system has revolutionised the field of surgical robotics there has been a rapid increase in the robotic surgery all over the world including developing countries like India. However there have been few barriers to adoption of this new technology–cost, extra training requirement and lack of robust data. The role of robot-assisted laparoscopy will be reviewed here.

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History of Robotics in Surgical Speciatilies

Surgical robots can be passive - where they can be programmed preoperatively to guide for a surgical target, these movement can be autonomous or [eg Probot] or it can be used for navigational aid for precise positioning. Surgical robots can be active where it is used for intraoperative surgical manipulation of instruments by the surgeon.

First robotic surgery was in 1985, where PUMA 560 was used to orient a needle under CT guidance for a brain biopsy [1]. PUMA was the first system to be approved by US FDA. Robotic surgery soon extended to other fields like urology (1988, Probot), orthopedics (1992, Robodoc), and gynecology (1998, Zeus) [1,2].

US FDA approved the AESOP [Automated Endoscopic System for Optimal Positioning], a laproscopic camera holder in 1994 for abdominal surgery; later a voice controlled system was used. These systems are no longer in use. The introduction of da Vince surgical system by Intuitive surgicals has revolutionised the surgical robotics. It was developed by Stanford Research Institute and National Aeronautics and Space Administration [2]. It was originally designed for military to provide surgical care to soldiers in battlefield form a remotely controlled surgical area. It was approved by US FDA in 2000; since then there has been a steep rise in the number of sale of da Vinci system and the number of robotic surgery across the globe.

Conventional Surgery Versus The Mininal Access Surgery

Conventional open surgery is time tested modality of treatment for many conditions. However as the technology for optics, camera and instrumentation has improved, laparoscopic surgery came with obvious advantage of significantly smaller incisions and better cosmosis, less pain, less bleeding, magnified view, early recovery etc. It was accepted with some skeptism and was initially criticised by many. Gynecologist were the first to embrace it and diagnostic laparoscopy and tubal ligations were accepted early. The first operative laproscopic surgery was laproscopic appendicectomy and was done by a Gynecologist Kurt Semm. Since then, as the technology became available to many, many more surgeons were trained in laparoscopic surgery and it was then accepted world over as a standard of care for many conditions. However it required mastering certain tasks eg hand-eye coordination, 2D vision, lack of haptics etc. Suturing and knot-tying, retroperitoneal dissection requires advanced surgical skills which are difficult to master. Poor ergonomics can lead to fatigue or joint strain in the surgeon, and prolonged surgery can be taxing for the surgeon [3]. In case of any difficulty in laproscopic surgery open surgery is savior. As the time has passed significant improvements have occurred in laproscopic surgery, both in technology and our skill and confidence in using them. Its safety and efficacy in undoubted now for many benign and malignant surgical procedures. It is still needed to choose laproscopic surgery carefully taking into account of the patient profile and the best possible treatment option to them.

Robotic Versus Other Surgical Approaches

Robotic assisted surgery is a type of minimal access surgery. Conventional laproscopic surgery and robotic laparoscopy share similar advantages over laparotomy, like significantly less morbidity, faster recovery, and smaller incisions. However both of these minimally invasive routes have similar potential to cause trocar injuries, insufflation related problems, abdominal wall hematomas at trocar sites when compared with laparotomy. There is slightly increased risk of bladder and ureteral injury with laproscopic and robot-assisted laparoscopy compared to open surgery as energy sources are used more commonly with both these methods [4].

Difficult laproscopically surgical tasks eg suturing and knotting, retroperitoneal dissection which are difficult to master with laproscopic surgery can be learnt and performed with robotic platforms much easily.

Advantages of robotic surgery

Robot-assisted surgery scores over conventional laparoscopy in many ways [5]:

Superior Vision: A robotic system provides a 3 dimensional view; camera can be rapidly zoomed to the area of interest by the surgeon himself without asking the assistants to do so; this allows the surgeon to have full control over the vision of the surgical field, while a conventional laproscopy has a 2D vision. Newer techniques for 3D vision are now being incorporated to laproscopy too but with a significant increased cost.

Mechanical advancement: Robotic instrument are far advanced as compared to laproscopic instruments. Instruments are introduced through the trocar in the abdominal wall, which acts as a fulcrum. This fulcrum effects puts a torque at the abdominal wall and the instruments which is further increased in obese patients. This leads to more tension on the instruments and hence more chances of breakage. Robotic instrument are introduced through the trocar too which are held in position by robotic arms, so much less torque is produced at the abdominal wall. This leads to less pain in the post-op period and less damage to instruments. Thin 3-5mm laproscopic instrument fracture more frequently due to this torque.

Wrist like movements: "Endo Wrist" movement in robotic hand ins of movement is very much similar to human hand. This facilitates suturing, hence suturing is easier to learn and do on robotic platform. Traditional laproscopes have 4 degrees of freedom, so learning and mastering suture and knot tying is difficult with a long learning curve. Surgeries which require lot of suturing and tying is difficult on conventional laproscopy while it is much easy to master on a robotic platform. Nowadays some laproscopic instruments are coming with few additional movement features, however it requires additional training.

All electrosurgical instrument are wristed in robotic platform while in laproscopy this function is available only with very few instrument.

Lessening of tremor: In conventional laparoscopy, small movements by the surgeon are amplified (including errors or hand tremor). Robot-assisted surgery minimizes surgeon tremors.

Instinctive hand movements: Hand movements are counter intuitive in laproscopy, if a surgeons has to lift up something he /she depresses her hand so the instrument goes up; this direction of movement is counter-intuitive to natural instincts. In robotic surgery hand movements are intuitive and in same direction as natural instinct; this makes faster with a small learning curve.

Ergonomic Improvement: Docking requires some additional time in robotic surgery than laproscopy. But with the newer 'Xi system' docking is easier and tak at the console while operating with robotic systems. This avoidance of long-term standing during surgery may be particularly helpful to surgeons who are pregnant or have orthopedic limitations [5,6].

In a study, 8-12% surgeons reported pain and numbness in their arms, wrists, or shoulders after performing conventional laparoscopic gastrointestinal surgery [8].

Limitations of robotic surgery

There are some limitations of robotic technology too [5,8]:

Instrumentation cost and limited uses for instrumentation: The cost of robotic surgical equipment is dependant on many factors eg- model type, spare hand instrument purchased, number of trainings for surgeon and Ot staff, single or dual console etc. For Developing countries like India the cost of procuring equipment and their recurring cost is too high; also each instrument is limited to 10 uses, and cost per instrument is very high. Cost-effectiveness of robotic surgery versus the conventional laproscopy surgery does not favours the robotic platform presently. One reason for this could be- it is presently being manufactured by a single company hence the cost is high; in near future as more companies will be manufacturing this equipment cost is likely to come down. Many other companies are like to come in market in coming years.

Additional training: for surgeons, technician and nursing staff.

Bulkiness of the devices hence need for bigger OT.

Lack of touch sensation or haptics just like laproscopy (tactile feedback)

Risk of mechanical failure: As with any other electro-mechanical device there is always a risk of mechanical failure and the instrument going haywire and causing injury to patient. Though the instrumentation goes to many quality checks and is smart enough to detect many of the problems/ or failures, the theoretical risk always remains there.

Limited vision to an area of abdomen: The older da Vinci systems required de-docking, repositioning and re-docking if more than 1 or 2 quadrants of abdomen we needs to be redocked if more than 1-2 quadrants are to be operated upon.

ROBOTIC Surgical equipment

The most widely used system is the da Vinci system. Equipment for this system includes [9]:

Surgeon's console (3D video screen, hand and foot controls so the camera, hand instrument and energy source can be controlled. It has a built in safety feature which allows the instrument activation only when surgeons head is put in the vision box. Surgeon can toggle between the instrument [Fig. 1]

Surgical cart (3-4 robotic arms on a boom, this boom can rotate and can go up and down for positioning at the patient end.) [Fig. 2]

Equipment cart (camera, light source, energy devices- electrocautery)

Fig. 1: Surgeons console

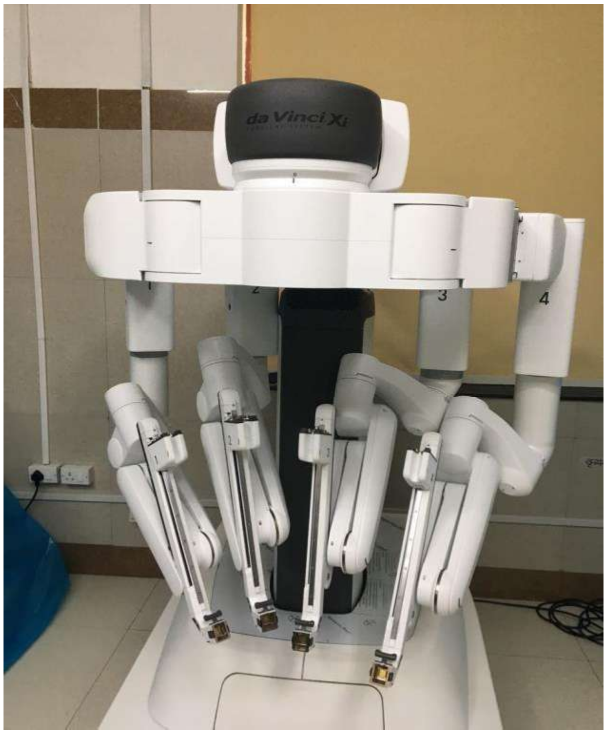

Fig. 2: Robotic arms with boom

Robotic Operative Procedure

Initially, the patient is positioned and prepared similarly to conventional laparoscopy. General anesthesia is given and verees needle is used to create pnemo-peritoneum, trocar is inserted [newer da Vinci system uses 8 mm port for camera as well as hand instrument]. Trocar is generally positioned at 15-20 cm from the target anatomy. Other ports are introduced 6-8 cm apart to allow for free movement of robotic arms on the left or right side of the central port. Assistant port can be chosen of 5-12 mm port size depending on which instrument would be required from the assistant surgeons. OT table can be tilted / moved prior to docking, and once robotic arms are docked on trocars, operating table cannot be moved. Ports are placed perpendicular to the abdominal wall in the newer robotic system so that it can be moved in any direction if other quadrant abdominal view/ surgery is needed. Earlier system required the ports to be placed at 15-30 degree angle, at 8-10 cm lateral to the camera port, this distance between ports is needed to avoid collision of the robotic arms.

A conventional accessory port is needed for suction/irrigation, introduction of sutures, removal of specimens etc; and is placed on the left or right side of the patient, superior and medial to the ipsilateral robotic accessory port. 8 mm ports can accommodate sutures with small half-circle (SH) needles and does not require fascial closure; this reduces musculoskeletal pain in the post-operative period.

The robot tower which has robotic arms is placed between the patient's legs, or centrally docked depending on the surgery being performed. Newer robot models can be "side docked" and allows free access to the lower abdominal quadrant and pelvic structures (eg, vagina, perineum). Older system required the robot tower to be positioned at 45 degrees to the patient's left or right leg stirrup or in parallel to the patient's bed. [6] For gynecologic surgery, side docking improves access to the vagina and perineum and reduce assistant fatigue and the potential for injury due to a collision with the robotic arms. Newer Xi Da Vinci system allows for easy positioning of the patient cart, with the boom rotating easily making docking easy and quick simplifying multiquadrant surgeries. Thin arms of the newer system allows for a greater range of motion and more flexibility

The surgeon is then seated at a console, views the operative area with a binocular vision system, and places hands on the hand controls. Height of Arm rest and view box can be adjusted and saved according to the surgeon'spreference and comfort. Hand 'masters'then translates the movements of the surgeon's hands into an electric signal which goes to the surgical cart and activates the robotic arms. Generally a ratio of 3:1 is used for movement of surgeons hand to the movement of robotic arm. Filter reduces the tremors of surgeons hand and allows for an efficient surgical manipulation and suturing. The surgeon can swap between the instruments. Foot pedals controls the camera, energy device and swapping of instruments.

The dual console system improves a surgeon's ability to teach a junior or trainee because both surgeons are able to sit at a console simultaneously, visualize the operative field in 3D, and swap control of various instruments. This function is specially helpful in medical colleges where teaching and training is a norm. Surgeon can control what all function he wants to give to his trainee allowing for a precise control over the movements of his trainee.

Newer systems employ optics that can provide high definition (HD) vision in three dimensions. Each instrument passes through a reusable 8 mm system-specific port [4]. Some robotic ports have valves, which allow insufflation through the robotic trocar.

Hurdles in implementing a robotic surgery: Major obstacles to the clinical use of robots are cost, extra training required [surgeons, technician and nursing teams], and lack of clear outcome data [5, 7,10,11]. There is no doubt that robotic technology is promising for the surgeons across all specialties to gain competence in complex minimal invasive procedures. This is particularly useful for surgeons who did not had advanced training or experience in complex conventional laparoscopic procedures that involve laparoscopic suturing, knot-tying, ureterolysis, retroperitoneal dissection etc.[11,12]

Robotic surgery in surgical training programs: Robotic training programs have become part of many surgical residency and fellowship programs in western countries, but such training is not standardized or essential. Currently, there are no guidelines or standard requirements for robot-assisted laparoscopy training in residency in other parts of the world [13]. Currently Intuitive surgicals asks to complete the on-line training module with >80% score, this is followed by 1-2 day training in a dedicated lab. This is followed by on site surgical proctoring of 3-5 cases [number is not fixed by the company] and is left to the credentialing hospital [13,15]. Additionally, there are five robotic training modules that must be completed online as part of the training. In India and many developing countries robotic surgical platform is available in a handful of government medical institutes; and still has not been included in surgical residency training.

Although there is a reliable and validated instrument that can be used to assess technical skills in performing robotic surgery (robotic objective structured assessment of technical skills [ROSATS]), it has not been widely adopted [13,14,15].

The surgeons must regularly do cases after acquiring the training to master the skills and should do cases regularly do maintain his/her skills. Many institutions are imposing a certain volume of cases so that surgeons maintain a competent skill level, however the individual variation in acquiring the competent skill level, makes an arbitrary number very illogical. Surgical learning requires adequate number of cases and the time interval in these procedures. It is also suggested that every specialities should develop how much time would be needed for acquiring specific tasks needed for every specialities. Proficiency in a new skill includes both the procedure and the ability to manage the complications. Safe surgical practice depends on surgical volume too, most agree that it is important that one should be proficient in open surgery before attempting robotic surgery, and if the procedure is performed exclusively laproscopically than the surgeons has to be competent in that field.

Cost-effectiveness of Robotic surgery: Cost of robotic surgery include capital required for acquisition of surgical robot, limited use instruments, team training expenses, equipment maintenance, equipment repair, and operating room set-up time. Results of cost-effectiveness analyses vary by whether single-procedure or overall robotic costs are included and by a hospital's surgical volume [10,11].

Robot-assisted cases [for hysterectomy] cost approximately $2000 more per case than the same procedure performed by conventional laparoscopy and varies greatly with the number of instrument used in each surgery. In the era of health care reform, and for developing nations this elevated cost may be the greatest hindrance to implementation of robotic surgery. Till cheaper robots are available this cost is likely to remain high and the benefits may not be passed to the general public. More prospective studies are required to analyze overall costs (direct and indirect) of robot-assisted procedures to health care systems before it is translated to clinical practice. Further studies are warranted to look into all these aspects.

The Future: Telerobotics in education and simulation:

Surgical simulation, telementoring, and telepresence surgery are potential novel emerging fields of robotic technology.

Robotic simulation could allow rehearsal of procedures with the potential for reduction in complication rates and learning curves, and even for the development of new technical approaches.

Telementoring provides the ability for an experienced physician at a remote site to be able to mentor a less experienced surgeon in training or in real time. The ability of a distantly located surgeon to perform surgery on a patient is exiting and opens the newer avenues of application of robotic surgery in future. Physical distance between an expert surgeon in a telementoring or telepresence set-up requires safeguards in case of mechanical failure or surgical complication (eg, latency of signal from mentoring to operating surgeon, redundancy of internet lines), although these have not yet been established [16,17]. The speed of information transmission is a key element in telepresence surgery. Surgeons are able to complete tasks with a delay in operating room to console signal transmission of up to 500 milliseconds. The US Food and Drug Administration requires that all operations using a telerobotic system are performed in the same room as the patient.

Conclusion

Robotic surgery has progressed rapidly all over the world in the last decade; it has been well accepted and adapted by surgeons across the globe due to its edge over the conventional minimal access surgery. It can overcome the limitations of the conventional laproscopic surgery, and has the prospective to expand its horizons further. Presently its high cost precludes its use in everyday surgery, and its availability is limited to bigger cities only. If only the cost can be taken care of, it has the potential to expand its use in every part of country with all the benefit passing over to the patients.

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