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Robotic-Assisted Gynecology: Expanding the Potential of Advanced Robotics

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Abstract

This short communication examines the advancement of robotic-based procedures in the medical industry. The surgical robot aims to increase surgical capabilities and address human shortcomings. Accurate and consistent repetition has been the key to robot's success. As an alternative to traditional open surgery, minimally invasive surgery (MIS) in gynecology minimizes trauma to surrounding tissues, reduces pain, accelerates recovery, and improves patient outcomes. Many gynecological procedures are now performed using minimally invasive approaches, such as laparoscopic and robotic-assisted surgery (RAS). In order to improve surgical maneuverability and physical abilities, robotic technology can achieve the following objectives and benefits. Laparoscopic surgeries using robots in benign gynecology, myomectomy, hysterectomy, endometriosis, tubal anastomosis, and sacrocolpopexy are all discussed in this study. There is little evidence to support the use of laparoscopic surgery (LAP) over traditional surgery for benign gynecological illnesses. In more complex operations, robotics does help. The conversion rate of robotic assistance to open surgery is lower than that of laparoscopy. Sutures performed by automated machines during myomectomy surgery are more effective and accurate than those performed by traditional laparoscopies. The automated program is a noticeable improvement overlap, and, if price issues can be resolved, it may become more popular among gynecological surgeons worldwide. We also discussed the main advantages and limitations of RAS in comparison to LAP in gynecology.

Keywords: Robotic-assisted surgery, Minimally invasive surgical procedures, Myomectomy surgery, Hysterectomies, Endometriosis, Sacrocolpopexy gynecological surgical procedures

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Introduction

During the last 30 years, gynecologic surgeons have expanded their surgical range to include marginally interfering surgery. The advantages of robot-assisted surgery include the ability to use joint-wristed tools, control tremors, and view and manipulate tissues in three-dimensional (3D) stereoscopic views. It was approved in 2005 by the US food and drug administration (FDA) for a limited range of gynecologic operations using the da Vinci Surgical System. Currently, the system is the only FDA-approved robotic stage on the market. There are a number of advantages to this platform over traditional laparoscopy, including less postoperative discomfort, improved surgeon ergonomics, quicker analysis of instrumentation curves, elimination of fulcrum effects, and a more ordered integration of fluorescence technology for lymphovascular estimation. Since the early 1980s, LAP has evolved steadily [1]. It has taken four decades for LAP to become a standard approach, despite its initial slow adoption. There is no doubt that LAP has a number of advantages over open surgery. In contrast to traditional open surgery, LAP minimizes damage to surrounding tissues by using small incisions and specialized surgical instruments. This results in reduced pain, reduced blood loss, fewer postoperative complications, shorter hospital stays, a faster recovery, and a lower morbidity rate [2].

Within the last decade, RAS has MIS in urology and has continued to do so. It was challenging for urologists to switch from open surgery to LAP because LAP comes with a steep learning curve [3]. RAS accelerated this transition by nearly tenfold, shortening the learning curve by nearly tenfold. During training in general surgery procedures such as hepaticojejunostomy and gastrojejunostomy, residents scored more nervousness and anxiety for laparoscopy than for RAS, according to a recent study. Laparoscopic drills performed better than robotic drills in terms of technical performance [4]. In contrast, RAS is being adopted more slowly in gynecological surgery. With a tendency to expand to new indications, RAS has now been used for hysterectomy, oophorectomy, salpingectomy, myomectomy, ovarian cystectomy, lymphadenectomy, endometriosis surgery, sacrocolpopexy, and pelvic exenteration, among many other benign and malignant conditions [5]. A relatively rapid transition has been occurring in hysterectomies, the most frequently performed major gynecological surgical procedure. Hysterectomies performed with RAS were proven to be noninferior to those performed with conventional LAP. As a result of shorter hospital stays, intraoperative complications and, therefore, conversion rates were either unchanged or reduced in RAS, though one study found that robot assisted surgery caused more postoperative pain than LAP (Figure 1).

Study after study has reported significant reductions in open surgery rates due to the benefits of MIS in gynecological surgery [6]. The surgical community is interested in developing awareness and accelerating the adoption of more advanced technologies in robotics in gynecological surgery, according to a number of recent published reviews. The use of MIS to completely replace traditional open surgery

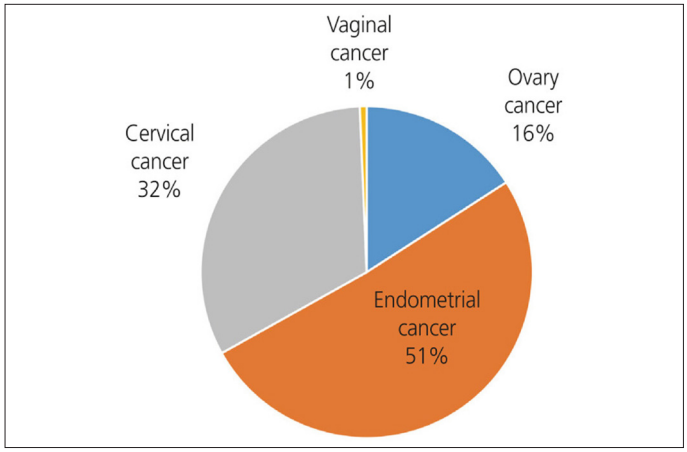

Figure 1: A decade's worth of robotic surgeries by cancer type [6].

continues to be hindered by a few factors, despite recommendations from international guidelines. Conventional laparoscopy is capable of performing nearly all surgeries performed by gynecologists, and advanced technology does not appear to be required in the future. The community still has a difficult time accepting RAS [7]. Does this have anything to do with technological limitations, accessibility, or both? Furthermore, we discussed the advantages and limitations of RAS compared to LAP.

Endometriosis

LAP for endometriosis is tricky. With low reproductive results, the adherence of adnexal structures, and the dysfunction of adnexal structures, the surgeon is under more pressure to perform an absolute and thorough operation [8]. A woman with endometriosis usually has prolonged pain in the pelvis, severe cramps and heavy blood flow, subfertility, excessive bleeding during menstruation, and abdominal bloating, and needs care during surgery to replace anatomy and function while all endometriotic implants are removed. In general, space is seen as an accomplishment of a surgeon following LAP for endometriosis [9]. Through robotic assistance, it is possible to overcome the space and give the surgeon a full and expanded view of the surgery. Nowadays, endometriosis is mostly treated with surgical aids using automated technology to illustrate the steps involved in clearing endometriosis [10]. Blood loss, clinical rest, and difficulties were not significantly different between RAS and traditional surgery for endometriosis. The procedure did not transform into laparoscopy. A robotic perspective may be more productive in complex surgeries with specific organ compromises because there are no modifications required. Segmental bowel operations, excision of nodules from the rectovaginal septum with or without rectal shaving, and partial bladder operations are known RAS procedures for deeply penetrated endometriosis. No specific perioperative difficulties were reported, but anastomotic discharge was seen [11]. One of the most comprehensive robotic procedures for deep infiltrating endometriosis has been performed here.

Hysterectomy

Over the years, marginally interfering techniques have been developed to make hysterectomy easier and less complicated, and it has become one of the most common surgeries in gynecology around the world. Even so, both in India and the USA, the number of open hysterectomy operations has increased. By doing as many laparoscopic or vaginal hysterectomies as possible, the goal should be to minimize any interference with the uterus. As a result, there is a reduced risk of postoperative illness and quicker healing. Several hysterectomy procedures for benign conditions should also be performed through the vagina or through laparoscopy, according to the American association of gynecologic laparoscopists. The RAS procedure is not widely performed or received in gynecological surgery, despite marginally interfering procedures being used for hysterectomy. There is a steep learning curve and perhaps it is technical difficulty. Robotic hysterectomy is more commonly performed with a robotic platform, whereas abdominal hysterectomy (AH) is less common [12]. As expected, mechanical techniques have been adopted more quickly than laparoscopic procedures for gynecology surgeries, mainly uterus removals, in the past few years. While RAS for benign gynecological illnesses did not result in better performance, it raised the price of the procedure. Its clinical results, including blood loss, difficulties, and clinical rest, were comparable to those of robot-assisted and laparoscopic hysterectomy (LH). Women who have a hysterectomy for benign disease may find that vaginal hysterectomy (VH) is preferable to LH and AH due to the fact that it allows them to return to their regular activities as soon as possible. It is preferable to have a VH instead of an AH if it is technically feasible for this reason, as it will heal more quickly and result in fewer febrile episodes [13]. A LH offers a number of advantages over an open hysterectomy, particularly in situations where a VH is not feasible (such as a faster recovery time, more frequent hot events, injury, and infection of the abdominal wall). Although these benefits are offset by a longer operating time (OT), they are still worth considering [14]. Total and radical hysterectomies are the most popular treatment options for endometrial and cervical malignancies in their early stages. A surgical procedure can be carried out openly, laparoscopically, or with minimal interference from robots.

Sacrocolpopexy

Female pelvic organ prolapse is a leading cause of morbidity in women, and more women are choosing surgical treatment over enduring discomfort and indignity. Approximately 0.2% to 45% of vaginal vault prolapse cases have been documented. Choosing the right course of action is heavily influenced by the surgeon's experience. In addition to the level of fitness the patient has for surgery, their age at presentation, and the degree of prolapse they have, the procedure available to them is also influenced by what they expect from their procedure. Among abdominal sacrocolpopexies with mesh, the rate of success is highest. With robotic-assisted laparoscopy, patients with pelvic organ prolapse who are otherwise healthy can recover quickly. According to data from level III, robotic sacrocolpopexy produces results comparable to open sacrocolpopexy. There are several advantages to robotics, laparotomy, and laparoscopy, including precision dissection, ease of use, and safety. The advantage of robotic assistance is that less blood is lost, and less time is spent in the clinical recovery area [14]. A mechanical method provides increased vision and talent, especially after the presacral region is dissected, the mesh is placed, and intracorporeal sutures are applied. In LAP, robots facilitate the adequate performance of challenging tasks and result in positive outcomes. Intracorporeal suturing is made easier with robotic sacrocolpopexy [15]. A mechanical assistant may assist with the entire surgery or just the surgery. This process contrasted with the operative time. In 2004, robotic sacrocolpopexy was described for the first time. The researchers used an automatic suturing aid in this study, and four women experienced recurrent prolapse or vaginal mesh extrusion-the average OT [16]. A comparison of patients' ages, body mass indexes (BMIs), and concurrent surgeries was conducted. According to statistics, the automated group has boosted OT while reducing surgical blood loss and length of stay. Generally speaking, both groups' assessments of postoperative prolapse in patients were similar. Nonetheless, as more procedures are performed by the surgeon and the team, the time it takes to perform an operation decrease. The recovery

time of patients who underwent robotic sacrocolpopexy was reduced by 25% and plateaued after that. It is true that robotic surgery is more expensive and takes longer to complete, but it tends to improve pelvic support and sexual performance. In the field of marginally interfering surgery, robotic surgery is the most recent advancement. The procedure offers surgeons improved visualization and dexterity, allowing them to perform intricate procedures beyond their capabilities with traditional laparoscopy. Laparotomy would result in high morbidity [17].

Myomectomy

In 1931, a surgical procedure called abdominal myomectomy was introduced to allow women to keep their uterus. Laparoscopically, an identical procedure was performed in 1979. A successful endoscopic surgery led to the development of robotic myomectomy (RM), which was accepted by surgeons. As automated platforms offer many benefits, they are particularly beneficial to surgeons who have little or no laparoscopic experience, particularly those who perform suturing. Suturing is a challenging aspect of myomectomy, and robotic arm aid makes the procedure easier and faster. It is for this reason that RM has gained so much popularity and acceptance. In comparison to a traditional open myomectomy, RM ensures the treatment will be as successful. There is no difference between laparoscopic and robotic surgery as far as acceptance and safety is concerned [2]. As of now, there are no randomized control studies comparing robotic surgery with conventional laparoscopy, the current standard of care for diagnosing and treating endometriosis. In terms of the benefits of robotic surgery for endometriosis in its early stages, there remains uncertainty. As a surgical treatment for uterine fibromatosis, MIS has become increasingly important.

In gynecology, robotic surgery has developed rapidly. In gynecological surgery, the robot has been used widely, particularly in reproductive surgery, as it has several advantages over traditional laparoscopy. Among the benign tumors of the female reproductive system, uterine fibroids are the most common. A number of reproductive-aged women had this condition, requiring uterine-sparing surgery to preserve their fertility. A repeatable and rapidly learned method of treating submucosal fibroids is hysteroscopic myomectomy. The use of robotic assistance reduces the technical difficulties associated with laparoscopic myomectomy for intramural and subserosal fibroids [18]. By combining these technologies, more patients with fibroids will be able to benefit from a marginally interfering treatment.

Advantages of RAS

There is no doubt that robotic assistance for surgeons has many advantages. Due to their inability to deflect at the tip, laparoscopic instruments have limited degrees of freedom of movement. In comparison to traditional laparoscopic instruments, robotic instruments offer a greater range of motion. Enhanced dexterity is especially useful when performing intricate surgical steps such as suturing, fine dissection, or delicate tissue manipulation. Additionally, robotic instruments can mimic the movements of a human wrist, allowing greater flexibility when maneuvering in confined spaces. Furthermore, robotic systems eliminate hand tremors, allowing for steady, precise movements. This is especially beneficial for tasks requiring high levels of precision. In addition to being stable, the camera can be controlled by the surgeon at any time. By avoiding communication with the assistant and maintaining picture stability, this leads to a higher level of concentration in the area of interest. First, Advincula and Reynolds suggested that robotics might be able to overcome the technical limitations of conventional laparoscopy in hysterectomy cases that obliterated the anterior cul-de-sac.

During long procedures, surgeons operate robotic systems from a comfortable console, which reduces physical strain and fatigue. Ergonomics can improve surgical precision. According to a recent systematic review and meta-analysis, 82% of gynecological surgeons who perform laparoscopic procedures suffer from musculoskeletal symptoms. It is more likely that these symptoms will occur after lengthy or complex procedures like a sacrocolpopexy. Since robotic surgeons sit in an ergonomic position, they are less likely to suffer work-related musculoskeletal disorders than LAP surgeons. A surgeon's career length could be affected by this factor. When compared with other surgical approaches, the use of robotics may provide certain advantages, such as autonomy when limited or no assistance is available. Robotic assistance has unquestionable advantages for surgeons, but its impact on surgical performance and benefits for patients remains controversial [19].

In technology adoption, are RAS and LAP equivalent?

According to comparative studies, OT is similar between the two approaches and occasionally reported to be longer for RAS, although there is also evidence to the contrary. It is imperative to receive appropriate training on robotic devices in order to ensure patient safety as well as the appropriate use of technology. Surgery has a steep learning curve, and not all surgeons have access to adequate training. Learning and mastering advanced endoscopic operations is not an easy task. It is possible to lose performance even with years of experience using LAP due to its inherent drawbacks. With a 2D endoscope, depth perception is lost, the video camera is unstable when held manually, dexterity is limited, LAP surgical instruments are counterintuitive and limited to move (due to the trocars enforcing fixation and not allowing for deflection at the tip), the fulcrum effect, and the surgeon and their assistants are unable to work ergonomically over long periods. Recently, innovations in endoscopic systems, such as high-resolution 3D cameras that enable better exposure and anatomical mapping of the operating space, have further improved surgical performance. It has become easier for surgeons to navigate anatomical structures with greater clarity, which has resulted in better outcomes and a shorter operation time. Laparoscopic surgeons rarely use standalone 3D endoscopic cameras in the OR, even though they are available [20]. By combining better 3D visualization with instrument control without counterintuitive movements (as is the case with LAP), a robot should have a faster surgical learning curve than LAP. Robotically assisted hysterectomies show significant reductions in operation times after the first 30 operations. Some surgeons rely on haptic feedback for precise adjustments and judgement during laparoscopic procedures, but they do not always compensate for the lack of it. Neuro-adaptation skills must be acquired during this transition. Maintaining surgical skills requires regular practice and the use of robotic systems. Infrequent users of the system may have difficulty maintaining proficiency. Nurses must also be taught how to use a robot system. Learning curves for RAS are already smoothed by MIS training and LAP experience.

Advantages of LAP than RAS

Although robotic surgery offers numerous benefits, it can be limited by certain practical aspects, such as the large footprint of the robot and the sterilization processes involved. In the operating room, robotic surgical systems such as the da Vinci Surgical System typically take up a lot of space. As a result of this large footprint, it can be difficult to arrange surgical equipment and personnel at the bedside to avoid collisions during procedures. It may be difficult for small operating rooms to accommodate large robots, which could result in logistical issues and reduced maneuverability [21]. In some cases, the size of the robot can make it difficult to access the patient or surgical site. A robotic system may require additional investments in infrastructure, such as

changes to the operating room layout and electrical system. It can be time-consuming and costly to make these modifications. Due to this, we see the emergence of new robots that propose a variety of modalities and separate carts to distribute around a patient's bed. Da Vinci Surgical System, vs Surgical Robotic System, and HUGO RAS System are three examples of four-arm robotic systems currently available on the market. In the OR as well as in the workspace above and around the patient, the total volume of the robot arms contributes to the bulkiness of the system, whether integrated into one unit or carried by four separate ones. In addition, the surgical staff is often forced into ergonomically unfavorable working positions, accelerating their fatigue and hindering optimal patient access, leaving little room for the assisting staff. With LAP, the surgeon remains surrounded by his surgical team at all times at the bedside of the patient. Instruments are controlled directly by him, providing tactile feedback (haptic feedback) and direct manipulation [22]. The da Vinci closed surgeon consoled has some limitations, including difficulties interacting directly with the surgical team. It can be challenging to make critical decisions if you need to communicate with the surgical team immediately. As reported in the study conducted by AAGL on experienced robotic surgeons in gynecology, more than half still experience physical symptoms caused primarily by a lack of confidence in managing ergonomic settings at the console [23-25]. In newer robotic platforms, the surgeon can stand or sit in an open console, facilitating visual communication with the OR staff. Despite their enhanced dexterity and precision, robotic systems can pose technical challenges during surgery. It is possible for procedures to be disrupted by malfunctions or technical problems. The surgeon can also perform endoscopic surgery with robotic systems only if the ports are placed properly and no arm collides with any other arm. In order to ensure patient safety, robotic instruments that are not single use must be cleaned and reprocessed properly. Compared to laparoscopic instruments, robotic instruments are more complex to reprocess, require specialized training, and require more maintenance. Costs associated with these procedures are high, it is time-consuming, and it may have an impact on the efficiency and scheduling of patient care in the OR. The majority of impacts on the environment are reduced by reusable robotic instruments, except for water consumption [26].

Recently published articles on Dexter Robotic System, which may be a potential alternative to traditional robotic systems. Dexter consists of a modular robotic platform with an open, sterile, and ergonomically designed surgeon console and two patient carts, each with a robotic arm. Furthermore, it incorporates a robotic endoscope arm that can be controlled from a surgeon's console and accommodates any 3D endoscopic system. With the console's endoscope and clutch pedals, the surgeon can maneuver the instrument and adjust the field of view with ease [3, 27]. With Dexter, surgeons can choose from a variety of 3D/fluorescence imaging systems, allowing them to customize their workflow. As a result, it is possible to incorporate cutting-edge imaging systems with routine updates or retain existing 3D/fluorescence imaging systems already in place in the OR, integrated into the conventional LAP configuration. Energy devices can also benefit from this open platform approach. Regardless of the operating room setting, Dexter seamlessly integrates. Since it is mobile and lightweight, it is convenient to transport between rooms and can be used by multiple operating rooms and surgical departments at the same time. By doing so, not only does the hospital's robotic system operate more efficiently, but it also maximizes its effectiveness. A compact form factor makes the whole system easy to store and frees up space in the operating room when not in use.

Due to the inherent costs of RAS, most robotic surgeries in gynecology are performed for malignant indications. There are many procedures that can be performed using RAS, including hysterectomy, myomectomy, sacrocolpopexy, endometriosis surgery, and some others. In comparison to LAP, RAS surgery was associated with increased incremental disposable costs per case and total hospital charges [28]. A robotic platform, however, is a tool for multiple applications, not a therapy, and needs to be evaluated according to that definition. The International consensus panel acknowledges that individual procedures-by-procedure assessments may not be appropriate [29, 30]. Increasing technological advancements in the market have led to the emergence of newer robotic surgical platforms. A number of important areas are being targeted for innovation as they compete with the established da Vinci Surgical Systems: surgeon ergonomics, visualization, the incorporation of haptic feedback, and reducing the overall footprint. This includes reducing the size and number of incisions as well as making the robotic platform more compact.

Conclusion and Future of RAS

As a result, robotic surgery has become more common in gynecological surgery worldwide, both in malignant and benign situations, particularly in the last 10 years. As a result of advanced assisted technology, there is no shaking of hands during the surgical procedure, minimal blood loss, and fewer open wounds after surgery. Because of the rapid healing process and quick recovery, the hospital stay for the patient is reduced. There is no risk to the patient. As a result of robotic surgery, precise and accurate surgery is ensured. Women who undergo myomectomy, hysterectomy, and pelvic organ prolapse surgery can benefit from robot-assisted surgery. Several growing conditions can be improved and corrected with robotic surgery, and infection risks can be reduced. A good alternative to open surgery is a fast-growing technology. It is not only used in gynecology, but also in neurosurgery, orthopedic surgery, colon endoscopy, benign prostate surgery, urology, general surgery, respiratory surgery, and cardiac surgery. By enhancing the intuitive controls of robotic systems, improving real-time feedback and visualization, and providing comprehensive virtual training environments to facilitate skill acquisition, further technical development in RAS and surgical platforms integrating concurrent technological advancements should continue to flatten the learning curve for robotic surgeons. By doing so, surgeons with all levels of experience can transition to RAS more easily and more quickly. The surgeons will be able to adopt robotic technology in the OR as they experience all the benefits of RAS and expand its portfolio for complex gynecological surgeries.

Acknowledgements

None.

Conflict of Interest

None.

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