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A multidisciplinary evaluation of robotic-assisted surgery effectiveness and its implications for healthcare education and practice - review of literature

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Abstract

The following work is a review of the literature on the use of robots in the operating room in various fields of surgery. Due to the progress of medicine and technology, the management of a patient requiring surgery is changing and new technologies are increasingly being used, including robotic surgery and the da Vinci robot. They have found application in various fields of surgery, such as urology, gynecology, general surgery, and cardiothoracic surgery, examples of which are described in the following work. Both its positive aspects, which include precision, better visibility of the operating field and the possibility of visualization in 3D HD technology, have been discussed. On the other hand, there are also negative aspects such as the need for specialist staff training and the cost of surgery using a robot. All of the above should be taken into account when qualifying the patient for the method of performing the surgery and considering the possible benefits that he or she is able to achieve. The use of this treatment method requires an individual approach and the determination of specific indications and contraindications to ensure the greatest possible safety and the best possible outcome.

Introduction

Robotic surgery has allowed for the development and change of existing methods of performing surgical procedures in various branches of medicine, significantly improving patient prognosis and the safety of operations.

Purpose of work

This study aims to compare the application of robotic surgery with classical surgical methods and laparoscopy.

Material and methods

The work is based on the analysis of available scientific publications, clinical reports, and data from medical databases such as PubMed, Scopus, and Cochrane Library. A literature review was conducted on the application of robotic surgery in urological, gynecological, general, and cardiac surgery. For the analysis, studies published between 2010 and 2024 were selected, which met the following criteria:

1. They concerned surgical procedures performed using a robotic system.
2.They compared the outcomes of robotic surgical procedures with traditional methods, such as open surgery or laparoscopy.
3.They evaluated key indicators such as operation time, blood loss, postoperative complications, length of hospitalization, and patients' quality of life.

Results

Many studies show that robotic surgery is as effective and safe as other surgical techniques. In certain aspects and clinical situations, it may be a better alternative; however, more research and observations are needed to accurately determine the potential greater benefits of using robots in the operating room.

Keywords

Robotic Surgery, Robot-Assisted, Da vinci Surgical System, Laparoscopic Surgery

Introduction

The first idea of robotic surgery (RS) emerged in the 1970s and was initiated by the United States Defense Advanced Research Projects Agency through the National Aeronautics and Space Administration. (NASA). Both organizations attempted to create a system aimed at conducting surgeries remotely.[1] The first success turned out to be the Puma 560 assembly machine, which was used in neurosurgery for brain biopsies.[2] The precision of the performed procedure was better than all previously used techniques.

The history of the da Vinci robot dates back to 2000, when it was approved by the Food and Drug Administration. (FDA). The components it consists of are: arms and a console. The console allows the operator to precisely control the operating field using an endoscopic camera mounted on one of the machine's arms. The other arms contain surgical tools such as grips and joysticks.[3]

A significant advantage of using a robot in the operating room is the presence of a tool with mobility resembling wrist movements over a wide range,greater than that enabled by endoscopic tools. Additionally, in robotic surgery, tremors are eliminated, which ensures greater precision of movements.[4]. An undeniable benefit is the better cosmetic effect after procedures using a robot, due to the significant reduction in incision size and the avoidance of laparotomy or thoracotomy. According to the observations of Javier Gallego-Poveda et al., there is a noticeable reduction in blood loss and the need for postoperative transfusions with robot-assisted surgery.[5]

As a downside, many consider the lack of tactile feedback, which can be compensated by high-definition 3D visualization.[4] However, the high costs associated with robotic surgery significantly limit the widespread adoption of this method, allowing its use only in a few centers.[6]

Application of the robotic surgery

Urology

The standard treatment for prostate cancer (PC) was open radical prostatectomy. (RP). The primary goal of PC treatment is to resect as much of the tumor as possible, as well as to

reduce the likelihood of recurrence in the patient.[7] The da Vinci surgical system was first used by Jochen Binder in a pioneering robot-assisted radical prostatectomy in 2000.[8] Since then, the procedure has become widely known and practiced in many countries around the world. Studies conducted since then have confirmed the benefits of using robotic surgery compared to currently used methods, particularly in terms of reducing perioperative complications, improving urinary incontinence, and achieving faster return of erectile function.[9,10] Radical prostatectomy can be performed without peritoneal access by using innovative single-port (SP) transperineal (TP) and transvesical (TV) approaches.[11] The surgery is performed in the Trendelenburg position, which facilitates the operator's access to the pelvis. After the prostate is removed, the urologist reconstructs the urinary tract by suturing the urethra to the bladder. The procedure lasts 2-4 hours, and the patient spends 2-3 days in the hospital. According to the risk stratification described by the National Comprehensive Cancer Network, RP is the first-line treatment for patients, particularly those with favorable intermediate risk and unfavorable intermediate or high risk with an estimated expected average life expectancy greater than 10 years.[12]

Another procedure performed using robotic surgery is radical cystectomy. Despite the fact that the standard approach is still open radical cystectomy (ORC), laparoscopic radical cystectomy (LRC) and robot-assisted radical cystectomy (RARC) are increasingly being performed. (RARC).[13] A serious threat is primary bladder cancer, which affects smokers as well as older individuals.[14] Many of the patients suffer from cardiovascular, kidney, or lung diseases. RAAC in this group leads to a reduction in perioperative complications and a shorter recovery time.[15] A randomized study conducted by Brennan P and the team did not show an advantage for RAAC with pelvic lymphadenectomy compared to ORC. The reference points were complications occurring within a 90-day period, quality of life at 3 and 6 months, and the costs of the procedure.[16]

General Surgery

The da Vinci robot has found wide application in general surgery, bringing a new quality to the treatment of many conditions, such as hernias, gastrointestinal cancers, and gallbladder diseases. Thanks to the precision and ergonomics of the system, the surgeon has the ability to operate accurately in hard-to-reach areas, which is particularly important in minimally invasive surgeries.

Studies have shown that the use of robots in general surgery is associated with less blood

loss, a reduction in the number of complications, and a shorter hospital stay compared to traditional laparoscopy. For example, in the treatment of colorectal cancer, robotics allows for precise removal of lesions while preserving anatomical structures, which may improve oncological outcomes.[18] In the randomized ROLARR study, rectal resections performed using laparoscopic and robotic methods were compared. The results showed that robotics allows for greater precision, especially in anatomically challenging surgeries, however, the operation time was longer in the robotic group.[19] On the other hand, meta-analyses indicate that robotic resection of colorectal cancer is associated with better outcomes regarding the preservation of anal sphincter function and a lower rate of postoperative complications, which is of significant importance for patients' quality of life.[20]

Cardiac surgery

In cardiac surgery, the use of robots usually takes place exclusively in highly specialized centers and mainly concerns operations on the mitral valve, as well as coronary artery bypass grafting.[4]

The first mitral valve procedure in history using a prototype of the Da Vinci robot took place in May 1998 by Carpentier, while the first totally endoscopic coronary artery bypass (TECAB) was performed by Loulmet in 1998 using the Da Vinci System.[21, 22]

In a study conducted by Joseph Hadaya et al. in Los Angeles from 2016 to 2020, the complication rates and costs associated with robotic-assisted and open mitral valve repair were compared. Out of 40,738 patients, 9.8% underwent surgery using a robot. Mortality was comparable in the applied techniques (0.7% vs 0.8%, $p=0.78$). The number of complications was lower in surgeries using the robot: pulmonary complications (6.1% vs 8.1%, $p=0.04$), acute kidney injury (5.7% vs 8.5%, $p<0.001$), postoperative infections (1.7% vs 3.4%, $p=0.003$). However, it should be emphasized that the group of patients who were qualified for mitral valve repair using a robot had a lower disease burden (Elixhauser Comorbidity Index 3.9 vs 4.4, $p<0.001$) and after risk adjustment, no significant association was found between the chosen technique and the incidence of complications. The main differences concerned the length of stay and the costs of the procedures. Compared to the conventional method, the costs associated with hospitalization and performing robotic surgeries were $10,500 higher with a 1.3-day shorter hospital stay.[23] This was confirmed by studies conducted by Mihaljevic et al. where 261 people underwent posterior mitral valve prolapse repair surgery using a robot, with complete sternotomy (n=114), partial sternotomy (n=170), and mini-thoracotomy approach (n=114). No significant association was demonstrated between the method of surgery and

subsequent complications and mortality. It is worth noting that the median cardiopulmonary bypass time was significantly longer when using a robot (42 minutes longer than complete sternotomy), and the median myocardial ischemic time was on average 26 minutes longer than in the case of complete sternotomy. These studies confirm the comparable efficacy and safety of using a robot as well as conventional methods.[24]

The extended duration of the surgical procedure in the case of a robot means that in patients with multimorbidity and in a more severe clinical condition, the preferred method remains sternotomy, which is associated with a shorter operative time and less patient burden. The learning curve is significant here. According to the Cleveland Clinic, the reduction in procedure duration when using a robot only occurs after 200 procedures have been performed.[25] Further training of the team, gaining experience, and improving techniques can positively impact the duration of robotic surgeries, allowing for a greater number of patients to qualify for this technique, reducing the length of hospital stays, and enabling a quicker return to daily functioning.[26]

The use of robots in coronary revascularization surgery is not as common as in the repair or replacement of the mitral valve; however, there are several ways robotic surgery can be utilized in bypass grafting. Complete use of the robot means harvesting the left internal thoracic artery (LITA) with its assistance and anastomosing it to the left anterior descending artery. (LAD). Partial robotic assistance means that the LITA harvested using the robot is manually sewn to the LAD.[27] The robot can also be used in hybrid coronary revascularization, which combines both coronary artery bypass graft surgery (CABG) and percutaneous coronary intervention. (PCI).[28]

A 10-year follow-up of patients conducted by Sarah Nisivaco et al. who underwent robotic beating-heart totally endoscopic coronary bypass (TECAB) showed very good results, while also encouraging further development and use of robots in revascularization, despite many challenges associated with this technique.[29]

Gynaecology

In gynecology, there is a significant opportunity to utilize robotic surgery technology. In publications, its use can be found in procedures such as myomectomy, hysterectomy, surgical treatment of endometriosis, and treatment for pelvic organ prolapse.[30]

Robotic surgery allows for better maneuverability within the uterus, thanks to wristed

instruments with a greater range of motion compared to the surgeon's hand or a laparoscope.[31] However, in gynecology, the duration of procedures is also significantly longer than with laparoscopic and open methods.[32] Robotic surgery is more perceived as an alternative to laparoscopic surgeries than a superior technique.[33] Robotic surgery does not significantly improve the outcomes of performed procedures compared to classical laparoscopic and open techniques. The results of the studies are unclear, often contradictory, and more time and analysis are needed to determine which technique is ultimately more optimal. So far, few randomized studies have been conducted.

According to Özbaşlı et al., after analyzing a group of patients who underwent myomectomy by robotic surgery, laparoscopic surgery, and open/abdominal surgery, it was found that there was greater blood loss during robotic surgeries, the length of hospitalization did not differ significantly depending on the technique used, while the maximum VAS score results were significantly lower compared to laparoscopic and classical surgeries. This is consistent with many studies that suggest postoperative pain is less after robotic surgeries.

Özbaşlı's study suggests that minimally invasive myomectomy may be a better solution for young patients. Only in cases where we have large-sized uteri and fibroids, robotic surgery achieved better results due to improved visualization of changes and reduced postoperative pain.[34]

Studies by Barakat et al. on performed myomectomies, on the other hand, showed reduced blood loss and shorter hospital stays with the use of robotic surgery compared to the results obtained in laparoscopy and open myomectomy.[35]

Soto et al. in their randomized study found that there are no significant differences between the use of a robot and laparoscopic techniques in the treatment of endometriosis. Both the duration of the procedure, blood loss, the presence of complications, and the quality of life of patients 6 months post-operation were comparable.[36] Chen et al. reached similar conclusions in their meta-analysis. They also did not observe differences in the incidence of complications, length of hospitalization, or blood loss between robot-assisted laparoscopy and conventional laparoscopy in the treatment of advanced stage endometriosis.[37]

In a retrospective study conducted at the University Hospital of Würzburg between June 2017 and September 2019 by Dimitrios Balafoutas et al., analyzing 110 cases of patients who underwent both urogynecological and general gynecological surgery using a robot, no significant problems during the procedure or major complications were reported. This may

indicate the safety of using robots in surgery and encourage further research to seek greater benefits from their use.[38]

Discussion

Robotic surgery has revolutionized modern surgery, offering new possibilities in terms of precision and minimizing surgical trauma. This system, thanks to 3D technology and high-resolution imaging, allows the surgeon to perform complex procedures with greater precision than traditional laparoscopic techniques. In particular, in urological, gynecological, and cardiac surgery, the robot allows for reduced intraoperative bleeding, shorter recovery times, and minimal scarring, which improves patient comfort and facilitates a quicker return to daily activities.

Despite its many advantages, this technology has its limitations. The high costs of purchasing and maintaining the system constitute a significant barrier to widespread adoption, especially in countries with limited healthcare budgets. Moreover, the effectiveness of robotic procedures largely depends on the operator's experience, which requires extensive training.

At the same time, more research is needed to precisely determine the characteristics of patients and the types of procedures that can benefit the most from the use of robotic surgery. It is important to remember that the safety of the patient is paramount, and we should prioritize their well-being when choosing the appropriate surgical technique.

Conclusion

Robotic surgery seems to have efficacy and safety at least comparable to laparoscopy or the classical surgical method. Current studies ambiguously indicate the advantages and limitations of using robotic surgery, which currently serves more as an alternative than a superior choice compared to other techniques. Further observations should provide us with more data on this topic. In the future, further development of this technology can be expected, which may lead to a reduction in the costs of procedures, increased accessibility, and further improvement in clinical outcomes.

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