

Robotic Surgery in Healthcare Setting: Application, Current Advancements, and Future Perspectives of Robotic Surgery

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Abstract

Robotic surgery, utilizing computer-controlled robots, has transformed minimally invasive procedures. This review delves into its evolution, applications, and future impact on healthcare. The Da Vinci system is globally employed, providing surgeons' precision and flexibility. Originating in the late 1980s, robotic surgery has expanded across clinical domains. Specialized training is essential for surgeons entering this field. Various types of robotic surgeries offer benefits such as smaller incisions, quicker recovery, and improved outcomes. Pre-operative planning, involving imaging studies, plays a crucial role. Advantages include increased accuracy, minimal invasiveness, and improved quality of life. Challenges include robotic malfunctions, limited availability, and financial constraints. Future advancements include miniaturization, single-port robotic surgery, AI integration, predictive analytics, telesurgery, nanorobots, haptic feedback, and regulatory considerations. Balancing technological progress with ethical standards is crucial for ensuring patient safety and accountability. In conclusion, robotic surgery presents significant benefits and challenges, with ongoing advancements and ethical considerations shaping its future impact on healthcare.

Keywords: Advantages, challenges, Da Vinci system, future advancement, healthcare invasive, robotic surgery, telesurgery

INTRODUCTION

Nowadays, robotic surgery is considered the most advanced form of laparoscopic or minimally invasive surgical procedure. By using a computer-controlled robot to aid the surgeons in some surgeries related to common traditional surgery or open surgery, robotic surgery is less invasive with smaller incisions that results in less scarring and pain to the patient. Through robotic surgery, the surgeon can do the most complicated surgeries by making smaller incisions. The positioning and manipulation of

robotic surgical instruments are computer-controlled and self-powered which helps the surgeons with better flexibility and accuracy during the surgery [1].

Currently, general surgery has noticed remarkable changes in the application of robotic and other surgeries, offering uses like less-incision sizes and getting good outcomes in surgical healthcare settings. So, evolution of robotic surgery, mainly in terms of minimal invasiveness, has benefited advancements in surgical technologies. This review is taking look for impact of robotic surgery in future healthcare [2]. Robotic surgery stands out as an inventive form of minimally invasive surgery where all health professionals make use of small surgical

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instruments used into a patient's body through a series of small incisions. By using three robotic arms, surgeons are provided with a various range of motion during the procedure. A fourth arm is for high-definition, three-dimensional camera for clear visualization of tissues and structure of the human body during robotic surgery [3].

Robotic surgery is minimally invasive surgery, and it can be performed independently or sometime combined with open surgical methods depending upon the specific situations. Globally nowadays, Da Vinci system is used for robotic surgery which consists of three main parts, a surgeon cart, the surgeon's console, and a vision cart. All these parts work together, to help the surgeons to use and control robotic instruments accurately and effectively [4].

What is Robotic Surgery?

Robotic surgery is a modern approach to minimally invasive procedures, using computer-controlled robots. Robotic surgery makes smoother and minimizes tissue injuries during the procedure even surgeons can perform surgeries in small area of the human body [5].

History of Robotic Surgery

Robotic surgery has become innovative area in the field of surgical research, developed step-by-step over several years. It was introduced in the late 1980s. Now it is applicable in different area in clinical settings like cardiothoracic surgeries, pancreatic, and laryngeal cancer surgeries including spine, urology, and gynecology. The evolution of robotic technology has its own various advantages, like declining morbidity and enhanced cosmesis [6].

Who Performs Robotic Surgery?

A surgeon who desires to specialize in robotic-assisted surgery and wish to take training in this specific type of procedure by attending in fellowships involved in robotic and minimally invasive surgeries [7].

TYPES OF ROBOTIC SURGERY

There are various types of robotic surgeries to enhance a patient's surgical outcome.

Laparoscopic Surgery

Robot-assisted laparoscopic surgery uses computer-based surgical robotic tools with the least possible invasive procedures. This modified technique increases patient care and overall surgical end results by

- doing smaller incisions,
- minimizing post-operative pain including discomfort,
- speeding the process of recovery,
- less hospital stays, and
- rapid shift to regular activities.

Endoscopic Surgery

Using robotic assistance in endoscopic surgeries in various medical specialties, like urology, neurology, orthopedics gynecology, and thoracic. This aims magnificent advantages, such as less blood loss with smaller incisions, speed recovery times, and overall enhancement of surgical outcomes.

Prostate Surgery

Robotic surgery helps to treat prostate related problems like prostate cancer with robot-assisted prostatectomy. The possible outcome with treatment is controlling cancer, declining prolonged hospital stay, as well as minimal blood loss with speedy recovery.

Cardiovascular Surgery

Robot-assisted surgery used and implemented in various cardiovascular problems includes atrial

septal defect repair, patent foramen ovale repair, cardiac tissue ablation, and cardiac tumor removal and in treating coronary artery bypass, mitral valve repair, and tricuspid valve repair.

Gynecological Surgery

In gynecology, Robotic surgery innovated for treating conditions like hysterectomy, ovarian cystectomy, and myomectomy, uterine fibroids, pelvic prolapse repair, excessive menstrual bleeding, as well as gynecological cancers such as uterine cancer like ovarian and cervical.

Neurosurgery

Robotics neurosurgery is assisting to treat brain tumors, seizures, and other brain related problems with minimal invasive surgical robotic procedures.

Orthopedic Surgery

Robotic technology is being used to treat knee ligament reconstruction as well as knee and hip replacements, trauma, and spinal interventions successfully.

Others

Robot-assisted surgery engages in magnificent roles in multiple healthcare settings with advanced technology.

General Surgery

- Appendix related surgeries (Appendectomy)
- Hernia and its repair
- Problems of gall bladder (Cholecystectomy)

Thoracic Surgery

- Lungs and mediastinum problems and reduction

Urologic Surgery

- *Cystectomy*: Removal of urinary bladder
- *Prostatectomy*: Removal of prostate gland
- *Nephrectomy*: Partial removal of kidney

Gastrointestinal Surgery

- Surgical removal of pancreas, stomach, rectum, and colon [8].

PRE-OPERATIVE PLANNING AND PREPARATION: CRUCIAL COMPONENTS OF ROBOTIC SURGERY

Steps of Pre-operative Planning

- Make use of imaging studies like MRI and CT to look for anatomy of the client and targeting the surgery effectively.
- Finding the proper surgical approach by developing surgical plans.
- Observe for potential complications.
- The medical and medication history of the patient should be reviewed.
- Make use of advanced imaging and software techniques for effective pre-operative planning,
- Instruct the patient for fasting for several hours before the procedure to reduce the risk of anesthesia related problems.
- Administer antibiotics to prevent infection and anticoagulants to reduce the risk of blood clots in case needed.
- Bowel preparation should be done in case of organ visualization problem.
- Shifting patient to the operating table with general anesthesia make sure for proper access to surgical site.

- Finally, surgical team and surgeon cross-check the set up for the procedure [9].

ADVANTAGES OF ROBOTIC SURGERY

- *Increased accuracy and clarity:* This robotic surgery allows surgeons to plan the procedures more safely and effectively.
- *Minimally invasive nature:* Surgeons can make fewer incisions while doing procedures with low blood loss, including speedy recovery of the patients.
- *3D visualization:* For a better surgical outcome, these surgeries enable the surgeons for better visualization of the surgical site.
- *Improved quality of life and reduced complications:* This kind of newer technology improves all-round quality of life and decreases the risk of complications for patients.
- *Increased maneuverability:* There will be a reduced hospital stay, less post-operative pain, and tissue damage is possible because of surgeons can operate on challenging areas of the human body.
- Reduce surgeons' tremors.
- Reducing the risk of human error.
- Enhancing the knowledge of surgeons through visualization of anatomical structure.
- Declining risk of infection [10].

DISADVANTAGES OF ROBOTIC SURGERY

Robotic Malfunction

A careful examination during robotic surgery is very important because machines are made up of human beings so there is risk of malfunction and which leads to tissue and nerve damage during the surgeries and results poor patient outcome.

Less Available Centers

Still there are less available facilities in our nearby hospitals and even most of the hospitals are not properly equipped to perform advanced robotic surgeries.

Expense

Robotic surgery is utilized by only selected patients because of financial problems and tools used in advanced robotic surgeries are more expensive so all patients are not affordable.

Latency During the Procedure

Robotic machines consume more time for executing its work between the computer and robotic tool movements so sometimes surgeons are facing problems while operating emergency procedures [11].

IMPACT OF ROBOTIC SURGERY ON FUTURISTIC HEALTHCARE

Miniaturization of Robotic Systems

Micro-robotics is new innovation that helps in modifying healthcare system. These microrobots play very important role in delivering treatment, in case, if surgeons are not able reach the specific area for operating delicate structure of the human body.

Single-Port Robotic Surgery

It is a minimally invasive treatment in which by doing single incision numerous robotic instruments are used to treat the problems that results in less pain, scar, as well as speed recovery.

AI and Machine Learning (ML) Integration

AI and ML integration is helping the surgeons to make efficiency, data analysis, and decision making as well as operating specific surgery with minimal human interventions that promotes optimize surgical outputs.

Predictive Analytics

This predicts patients' safety as well as decision-making, medical history, finding potential complications, and real-time surgical information including overall surgical success.

Telesurgery and Remote Surgery

Telesurgery or remote surgery technology is helpful while delivering critical intervention during emergency because utilizing high-speed internet with robotics allows the surgeons to operate procedures remotely.

Nanorobots in Surgery

Nanorobots in surgery refer to nanomedicine, which help to detect early cancer, enhance tissue repair, and deliver medicine to target area with minimal side effects. Here, surgeons can expect accuracy.

Haptic Feedback and Sensory Augmentation

This technology is safer and more effective than surgeries because, here, surgeons have skills and control over their hands while operating delicate procedures like detection of tissues as well as suturing by simulating tactile sensations, which enables them to "feel" tissue resistance and texture.

Regulatory and Ethical Considerations

These regulations and ethical considerations are important to reduce risks, create accountability, enhance high standards of safety and quality in robotic surgery, follow guidelines while designing, process of manufacturing, and training of robotic surgeons and certification of equipment during future use of robotic surgeries [12].

CONCLUSION

Robotic surgery has emerged as a leading minimally invasive approach and is transforming traditional surgical methods. This review explores the current state, applications, and future impact of robotic surgery in healthcare. Utilizing computer-controlled robots, surgeons can perform intricate procedures with smaller incisions, reducing scarring, and post-operative pain. The Da Vinci system, widely used globally, showcases the versatility of robotic surgery in various medical specialties. Advantages include increased accuracy, minimal invasiveness, 3D visualization, and improved patient outcomes. Challenges such as malfunctions, limited accessibility, expenses, and procedural latency require consideration. Future prospects involve miniaturization, single-port surgery, AI integration, predictive analytics, telesurgery, nanorobots, and enhanced sensory feedback. The review emphasizes the evolving role of robotic surgery, combining technological advancements with ethical and regulatory considerations for a promising future in healthcare.

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