THE BLOSSOMING FIELD OF ROBOTIC SURGERY

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Abstract. *Technological advancements have reshaped various aspects of our world, and the medical domain is no exception. One of the significant innovations in medicine is robotic-assisted surgery. Compared to traditional surgical methods, robotic surgery offers numerous advantages, including reduced hospital stays, lower complication rates, and enhanced precision in procedures. However, these benefits must be balanced against longer intraoperative durations, initial high expenses, and the need for extensive training. The increasing adoption of robotic surgery in the medical field has sparked interest in understanding its mechanisms, advantages, and limitations. Ongoing large-scale, randomized, prospective clinical trials, coupled with a growing body of research, hold promise for addressing lingering uncertainties surrounding robotic surgery. This paper aims to delve into the factors contributing to the widespread acceptance of robotic surgery, exploring its evolution, technological underpinnings, and clinical applications. By examining the latest advancements and emerging trends in robotic surgical systems, this study seeks to provide insights into the transformative impact of robotics on modern surgical practices.*

Keywords: *surgical robot, three-dimensional images, complex operations, precision.*

Introduction

According to its definition, a robot is any automatically operated machine that replaces human effort, regardless of its resemblance to human beings or the manner in which it performs tasks [1]. This intrinsic fascination with exploring the uncharted territories of robotics has extended into various fields, including medicine. In the realm of healthcare, robotic systems have revolutionized surgical procedures, allowing for complex operations to be performed with heightened precision and quality. In contrast to traditional open surgery, where surgeons make large incisions directly on the patient's body, robot-assisted surgery allows surgeons to remotely manipulate minimally invasive instruments via a console, aided by a three-dimensional view [2]. This advancement has prompted a closer examination of the pros and cons associated with robot-assisted surgery, which will be discussed further in the following article.

How Does the Robotic Surgical System Work?

The practice of robotic surgery involves the use of tiny surgical instruments introduced through a series of small incisions into a patient's body. Instruments are mounted on three robotic arms, enabling surgeons to perform their procedures with the utmost accuracy and flexibility [3]. The surgeon operates these instruments from a nearby console, manipulating them to perform the necessary procedure [4]. To conceptualize this process, it is helpful to liken the Robotic System to a supercomputer, facilitating real-time translation of the surgeon's movements for greater precision. As part of a robotic-assisted surgery, the surgeon uses a surgeon console to direct the instruments during the procedure. Computer software converts the surgeon's movements into instruments that move within the patient's body exactly as the surgeon does.

Currently, the Da Vinci Surgical System, developed by Intuitive Surgical in the United States, is the most known surgical robot [5]. With its three-dimensional (3D) vision system, precise images are captured. Its robotic arms, which feature a refined motion control system, are skilled at performing more elaborate surgeries than the human arm can do (see Fig. 1).

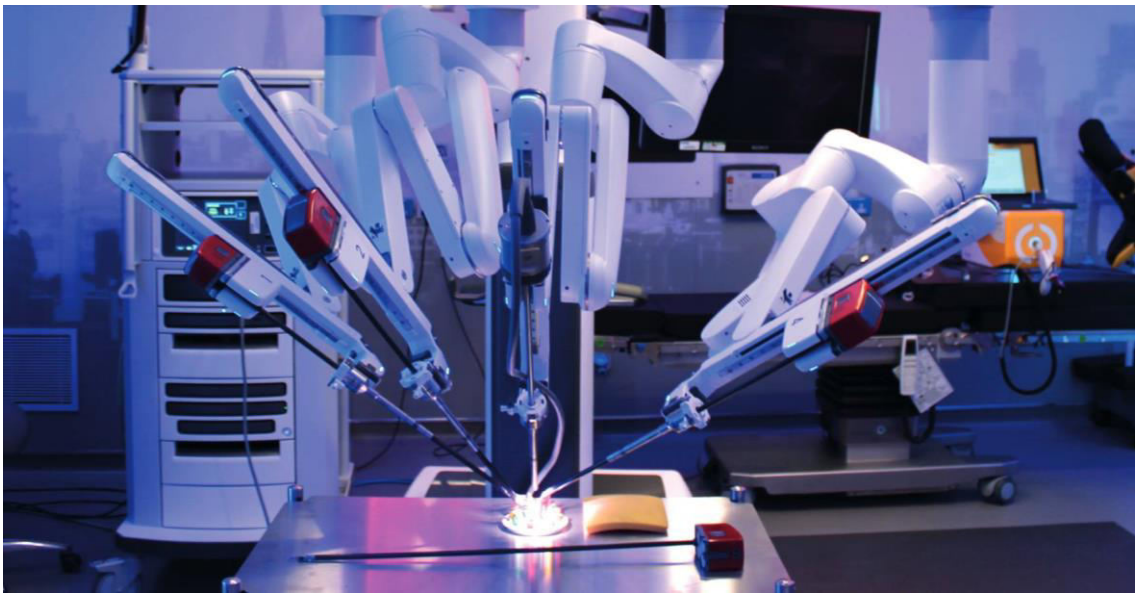

Figure 1. Da Vinci Surgical System [6]

Furthermore, robots have made it possible to breach the most enduring surgical paradigm that has existed for centuries: the surgeon's personal presence and "touch," together with their capacity to do surgery across continents, as was demonstrated with operation Lindbergh in 2001[7]. During this operation, a cholecystectomy was executed on a patient located in Strasbourg from New York. Tele-mentoring and tele-proctoring were established on this achievement, obstructing barriers, and promoting surgical knowledge sharing virtually anywhere [8].

To overcome some of the prevailing limitations of robotic surgery, several robotic systems have been brought to a more advanced stage. For example, the ISIS Scope/Anubiscop, among others, has successfully performed precise operations such as colonic and endoscopic submucosal dissections. These procedures were conducted using a telerobotic version called STRAS (single-access transluminal robotic assistance for surgeons), which incorporates a high-resolution scope [9].

Besides the first polypectomies, flexible endoscopy has developed into a diversity of new techniques, including endo-ultrasonography-guided drainage of pancreatic cysts and submucosal dissection, and then onward to more intricate techniques like the per-oral endoscopic myotomy (POEM), an endoscopic alternative to achalasia treatment [10].

An alternative to surgery without scarring, NOTES, encompasses accessing the peritoneal cavity through natural orifices to perform surgery without incisions on the skin [11].

Benefits and Challenges

There is ample evidence that general surgeons are becoming more and more enthusiastic about robotics. The firm that sells the da Vici surgical system, Intuitive Surgical, states that general surgeons are among the surgeons who complete the clinical pathway necessary for credentialing the most frequently [12]. Will the advancement of robotic technology transform the field of general surgery as we acquire more knowledge and expertise? Without a doubt, technology is amazing (see Fig. 2).

While two-dimensional laparoscopy makes it difficult to perceive depth accurately and long laparoscopic instruments increase tremor and only allow four degrees of freedom, three-dimensional images eliminate tremor and allow for intuitive manipulation of instruments in nearly any direction. Robotics also offers the benefit of camera stability that the surgeon fully controls and the capacity to perform single-site surgery with triangulation of the tools and camera, which does away with the necessary parallax associated with laparoscopy.

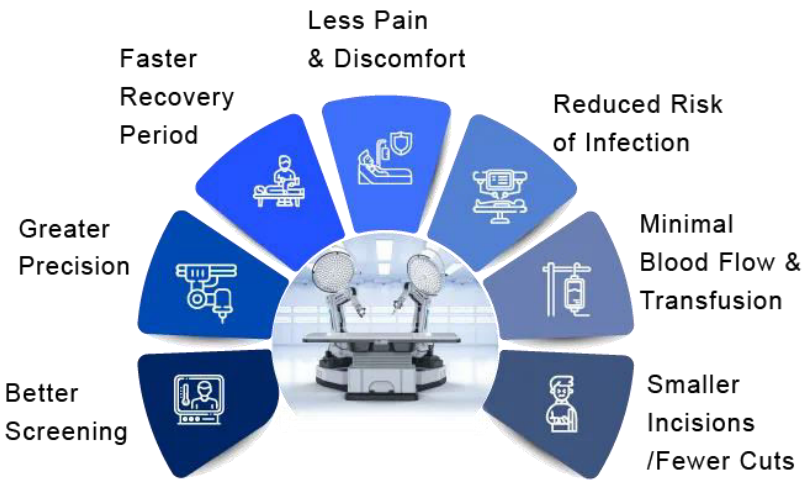

Figure 2. Key advantages of robotic surgery [13]

Undoubtedly, surgical robots have changed many aspects of medical life, including the recovery process of the patients. Scientists from the University of Sheffield and University College London conducted an academic study demonstrating the faster recovery of patients from robot-assisted surgery for bladder cancer excision, resulting in a significant (20%) reduction in hospital stay. The research, which was supported by the Champniss Foundation through a grant from the Urology Foundation and published in JMA, also found that robotic surgery significantly lowers the risk of readmission by half and shows a stunning four-fold drop in the occurrence of blood clots. In essence, this finding diminishes the risk of heart attacks [14]. Furthermore, researchers have reported that patients' physical activity, stamina, and quality of life also increased, as evaluated using daily step data collected by a wearable smart sensor.

Nevertheless, there is always space for development. Robot-assisted surgery, due to the technologies it employs, and the high costs associated with installation and maintenance, is only offered by facilities with specialized qualified surgeons and the financial means to cover these costs. Additionally, in surgical procedures, there is still a risk of nerve damage and compression. Addressing these issues will accelerate the adoption of robotic surgery and significantly enhance its value. As robotics technology is still in its infancy, ongoing advancements will likely make it even more beneficial for general surgery.

Considering the above, experts anticipate that with the ongoing advancement of technology, surgery will become even less invasive and increasingly digitalized in the future. It is expected that the incorporation of artificial intelligence and machine learning algorithms into robotic surgery will become increasingly significant in the upcoming years. For instance, surgical margins, which refer to the tissue surrounding a tumor that is removed during surgery, greatly influence the success of cancer treatments [14]. Normally, surgeons rely on intraoperative frozen-section pathology, a process where tissue samples are quickly frozen and examined under a microscope to determine if cancer cells are present at the edges of the removed tissue. However, this process can be time-consuming and can slow down the efficiency of the operating room. Therefore, experts highlight the potential of machine learning and spectroscopy advancements to improve this process. These advancements could allow surgeons to assess surgical margins in real-time during the operation, rather than waiting for post-operative pathology results. Furthermore, this could lead to quicker decisions during surgery and potentially improve patient outcomes that all cancerous tissue is removed while minimizing damage to healthy tissue.

Conclusions

To encapsulate, the future of surgery will be defined by a steadfast commitment to enhancing patient safety and quality of life. This objective will be realized through a strategic integration of computer assistance, image guidance, and robotics, ushering in an era of unprecedented precision and efficacy in surgical interventions. Moreover, the convergence of advanced techniques independently developed in radiology, surgery, and gastroenterology holds immense promise. By embracing a hybrid approach that harnesses the best features of each specialty, patients stand to benefit from optimized outcomes and enhanced care.

However, the realization of this vision necessitates radical transformations in operating room concepts and setups. As complex image-guided procedures become increasingly prevalent, ensuring a safe environment equipped with cutting-edge imaging tools will be paramount. In essence, by embracing innovation and collaboration across disciplines, the future of surgery holds boundless potential to revolutionize patient care and elevate the standards of medical practice.

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