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RESEARCH INVENTION JOURNAL OF BIOLOGICAL AND APPLIED SCIENCES 4(2):23-27, 2024

©RIJBAS Publications ISSN: 1597-2879

https://doi.org/10.59298/RIJBAS/2024/422327

Robotic Surgery: Precision and Patient Outcomes

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ABSTRACT

Robotic-assisted surgery has transformed modern surgical practice by offering new possibilities for precision and improved patient outcomes. This paper systematically reviews current evidence on the effectiveness, precision, and patient outcomes associated with robotic surgery, evaluating both its strengths and limitations. Although robotic systems are widely implemented across surgical disciplines, ranging from urology to gynecology, their benefits have been met with both praise and caution. This review examines areas where robotic surgery may outperform traditional approaches in minimizing blood loss, reducing recovery time, and enhancing surgical accuracy. Additionally, it discusses the economic and operational barriers to widespread adoption, such as the significant costs associated with equipment and training, as well as the variability in clinical outcomes reported in different studies. Despite these challenges, the application of robotic surgery in complex and minimally invasive procedures continues to grow, with data supporting improved patient experiences in specific cases. The conclusion emphasizes the need for further randomized clinical trials to definitively establish robotic surgery's impact on patient outcomes and to guide optimal usage in various surgical contexts.

Keywords: Robotic Surgery, Patient Outcomes, Precision Medicine, Minimally Invasive Surgery, Surgical Technology.

INTRODUCTION

Today, it is hard to imagine an operating room without a robotic system. Robotic-assisted surgeries are becoming increasingly popular among hospitals all around the world. Proponents of the technique emphasize its potential to give superior outcomes compared to other, simpler procedures. However, in contrast to this rosy picture, it is widely known that no convincing clinical evidence has been demonstrated up to now for this kind of approach. Limitations may be encountered, and the costs of robotic systems are far from negligible. The huge applications of robotic systems in surgery have left many open questions and unresolved issues. Robotic surgery has been proposed as a potential solution for enhancing the effectiveness and safety of surgical procedures, based on the idea of making the surgeries more precise compared to their traditional alternatives. Guided by the onset of this promising trend, the main objective of the present work is to evaluate the effectiveness and potential of introducing robotic surgery, to answer which issues it is more effective for, and whether the benefits outweigh the potential limitations. The following points will be addressed from a systematic review of research existing in the literature: has the precision of surgery, the outcomes of surgery, and the final results increased, and have there been any complications or drawbacks associated with the procedure? In the existing literature, very few papers have performed such a comprehensive analysis. Surgical procedures that have been significantly facilitated by the introduction of robotic surgery were subjected to a thorough analysis to provide insights and in-depth discussions on the different aspects. As a result, a comprehensive view of the possible advantages and limits of robotic surgery was depicted. The most exclusive studies in the field have focused on gynecology, prostate cancer, head and neck surgery, and minimally invasive surgery of the neck. The transition was not so successful in other areas, at least in terms of budget invested.

Moreover, negative effects of robotic surgery on the healthcare system have been reported. Lastly, in order to validate the enhanced outcomes of robotic surgery, adequately configured randomized clinical trials with a sufficient sample size and methodological soundness should be performed [1, 2].

Evolution of Robotic Surgery

When the concept of a robot that could assist or autonomously perform surgical tasks was first conceived in the late 80s to combat the limitations of laparoscopy, it was a significant leap in technology. This robot, the Probot, was developed in collaboration with British companies, and it was able to successfully suture in the lab with electronics. Later on, an enhanced prototype, based on the same fundamental concept, was able to function as a neurosurgical robot and assist one of the world's best. The journey from the idea of a technical robot with guiding arms like teleoperation to a fully electric steerable surgeon within a human body was realized in 2000 when a cardio-thoracic surgeon docked the robot to perform telesurgery [3, 4]. The field continued to see hype for telesurgery even in the 1980s and 1990s by research teams and publishers. As proof of concept, a robotic prostatectomy was performed for the first time in 2000. Of the major advancements in urology, the most widespread was the Da Vinci machine, which has provided for over 3 million surgeries worldwide. Some milestones to discuss are the journey of robotic surgery, which has been full of excitement, thoughts, non-believers, and adopters. The groundbreaking robotic telesurgery experiment was performed, and its existence was presented to the medico-legal community [5, 6].

Technology Behind Robotic Surgery

At the heart of robotic surgery are powerful robotic systems that serve as the surgeon's hands. Modern robotic systems can be quite complex, but at their most basic form, they consist of a master user interface, a robotic patient-side cart, and one or more interactive visual representation displays. The patient-side cart includes, among other components, the robotic arms that perform surgery under supervision and control from the master. These robotic arms typically provide at least three actuators of freedom, although some research surgical robots function with fewer [7, 8]. Advanced imaging technology is frequently integrated into robotic surgical systems, offering a clearer and more actionable visualization of the patient. This integration can include image guidance systems, which aim to use preoperative or intraoperative imaging to visually navigate surgical tools to a specific location of interest, or higher-end diagnostic scanning systems for direct visualization of the surgical target and related anatomy. Haptic feedback enhances a surgeon's sense of tool-tissue interaction and allows for cutaneous feedback, better simulating direct skin contact. Advanced visualization technology enables more comprehensive surgeon interaction through mixed-reality visualization, allowing for more natural eye-hand coordination, and enabling the surgeon to look and interact with anatomy in a way that is more natural and consistent with conventional open surgery. It also enables 3D visualization, which can make interaction easier and less error-prone [9, 10]. Software and algorithms are major components behind the capabilities and limitations of robotic technologies. Advanced software can allow robotic systems to plan, track, and account for contact with dynamic patient anatomy. Artificial intelligence is a rapidly growing field in the research and development of surgical robotics, offering new, multifaceted capacities to improve localization, motion planning, decision-making, adaptation, visualization, and more. Finally, robotic surgical systems are typically capable of interfacing with other medical devices, such as endoscopes, laser ablation wands, biopsy needles, resection instruments, suction instruments, sutures, and physical stabilizers, to streamline surgical workflows. In orthopedic procedures, robotic systems can also work with navigation systems to align positioning more accurately, among other advantages [11, 12].

Applications of Robotic Surgery

Robotic surgery developments have had a dynamic and transformative role in surgery, from gastrointestinal surgical applications to numerous other specialties. Urological robotic-assisted laparoscopic prostatectomy constitutes the majority of robotic surgeries performed. It is used for the precise dissection of pelvic nerves from the prostate during radical prostatectomy, increasing the number of surgeries. Robot-based laparoscopic procedures are used to treat pathologies in pediatric surgery, general surgery, endocrine surgery, trauma, thoracic surgery, gynecological oncology, lymphatic mapping, and intraoperative lymph node detection, as well as other applications. Robotic systems are used in clinical interventions such as urologic, gynecologic, and pediatric surgeries. Currently, there are more than 4,500 installed systems worldwide, and more than 1,985 surgical programs are performed daily using robotic surgery [13, 14]. Perioperative outcomes, such as intraoperative parameters, blood loss, urinary tract and sexual dysfunction, continence, margin, lymph node dissection, lymph node count, hospital stay, and anastomotic time, in 1,000 laparoscopic surgeries have been explained. This and more potential advantages satisfy the use of robotic surgery for inexperienced surgeons or those on the learning curve with greater safety and learning potential. Thanks to these advantages, it seems inevitable that robotic surgery will become the new standard of care. As robotic technology becomes more widely adopted, it is causing changes in surgical practices regarding patient care and treatment planning. For example, the presence of robotics in the operating room has become an increasingly decisive criterion for the choice of individuals who need surgery. Mainly because the potential benefits of the robotic approach for certain procedures are scientifically confirmed by validated data, the cost of surgery and hospital stays are important. Case series and retrospective studies show that urologic robotic surgery has since been performed with oncologic efficacy, low perioperative morbidity, and low post-operative complication rates, with anatomical pelvic benefits. Most patients are considered for robotic surgery in cancer centers. Robotic surgery has many crucial advantages that can be modulated depending on the robot used with specific instrumentation to meet the needs, safety, and ease of every surgeon. Clinical results, percentage decrease in early complications, earlier return to normal daily activities, consistently good aesthetic results compared to open surgeries, swift hospital discharge, and excellent hemostasis have been confirmed by extensive scientific evidence. This is scientifically a low agonizing operation. Studies demonstrate how the footprints in urologic clinical activity were imposed by robotic surgery, and the robot has represented the new gold standard for selected surgeries. Only experience can temper enthusiasm by selecting the cases and numbers to propose for minimally invasive surgery compared to conventional open surgery. A review of the scientific literature highlights how the number of uro-oncology robotic surgeries has made a difference in terms of mortality. For urologic surgery with neuroprecursors, the surgeon automatically decreases the perioperative tumor risk of up to two cases per 1,000 surgeries. This reduction in tumor risk is obtained exclusively with robotic or laparoscopic approaches. However, there is emerging evidence that is fundamental to patient safety, in addition to the instruments. Preserving tissue trauma from technology improves patient rehabilitation, especially in terms of recovery of physical mobility and urinary and sexual continence [15, 16].

Advantages and Limitations of Robotic Surgery

Robotic surgery provides a means of accessing operative cavities in the body that cannot be accessed using traditional open surgery, as well as hard-to-reach places, often with less blood loss and faster recoveries than older laparoscopic surgeries. Additionally, the access and recovery advantages of robotic surgery sometimes also result in faster discharges from the hospital. Surgeons find the view provided by the robotic system to be of greater depth perception, free of tremor, and providing greater magnification than the earlier generation laparoscopes, although each surgeon may have a different view on this. Moreover, other benefits to surgeons exist in the upper limits of hand and wrist motion enabled by the robotic tools, as the robotic arms rotate seven times by the wrist for every rotation of a human wrist [17, 18]. Robotic surgical systems require a capital investment for purchase and installation, as well as maintenance and consumable costs during the use of the robot. Robotic systems also require additional facility resources or effort to run beyond older laparoscopy systems, often including the opportunity cost of employing a technician full-time to help repeatedly dock and undock the robot cart from a patient. The use of robotic surgery has consequently been restricted to centers that can afford the capital purchase and recurrent maintenance and training costs. Some feel that newer robotic systems will become cheaper and robot programming will become more automated. While robotic surgery is part of the heterogeneity of medicine and not everyone should undergo robotic surgery, its physical assistance for complex tasks has enabled less bleeding and faster recoveries compared to traditional surgery. Robots are not foolproof, and healthcare providers are thus responsible for the skillful supervision of robotic technology. Surgeons may have to invest time across weeks to months in purely robotic surgery training fellowships beyond their surgical training, culminating in obtaining the essential certification to operate the robot in the operating room. Furthermore, in some complicated cases, a robotic system is not the best option. Costs are also considered when deciding if a robot is acceptable. Upfront shopping and prolonged maintenance prices are examined before a robot investment. Once again, many surgical centers see a costly venture in robotic assistance. If a robot stops working, things might get much worse than they envisioned. If there is no consistent guidance in the usage of advanced robotic systems, then it is better to avoid it. Yet, robotic surgery can lead to greater accuracy among experienced physicians, shorter patient trauma, and minimized recovery times, including smaller blood removal. These are some of the advantages of robotic assistance, and the procedure is generally chosen for complex surgeries and younger patients with much more challenging or unusual anatomy. There is no doubt that individual financial incentives have played a part in shaping several of these current results, particularly in the long run. However, cost is not the singular factor in minimizing the growth of robot-assisted surgery. Lacking the backup necessary to properly maintain and troubleshoot such complex technology at all working hours has been performed through several operating rooms. Ethical concerns about the usage of new technologies in patients and the influence of robotic surgery in the development of new surgical strategies, such as tissue development, have been justified and discussed in depth. Furthermore, every surgeon must consider obtaining thorough education and/or training before considering an innovation of any kind. There are intricate and advanced versions of the robot's purpose for surgeries. Every physician, patient, and surgery is unique [19, 20].

CONCLUSION

The development and implementation of robotic surgery represent a significant advancement in the medical field, with potential benefits for both surgical precision and patient outcomes. However, the adoption of robotic-assisted surgical systems remains a complex decision influenced by factors such as cost, training requirements, and specific clinical indications. This review highlights the areas where robotic surgery has demonstrated improved patient outcomes, particularly in procedures that benefit from high precision and minimal invasiveness. Yet, the lack of comprehensive, large-scale studies means that clear clinical guidelines for its usage are still evolving. As robotic surgery technology advances, the medical community must focus on rigorous, evidence-based studies to validate its efficacy and cost-effectiveness in diverse medical settings. A thoughtful and measured approach to incorporating robotic systems may ultimately optimize patient care while balancing the financial and logistical considerations involved in their use.

REFERENCES

1. Abbasi N, Hussain HK. Integration of Artificial Intelligence and Smart Technology: AI-Driven Robotics in Surgery: Precision and Efficiency. Journal of Artificial Intelligence General science (JAIGS) ISSN: 3006-4023. 2024 Aug 21;5(1):381-90. boulibrary.com
2. Williamson T, Song SE. Robotic surgery techniques to improve traditional laparoscopy. JSLS: Journal of the Society of Laparoscopic & Robotic Surgeons. 2022 Apr;26(2). nih.gov
3. Ragusa A, Prata F, Iannuzzi A, Tedesco F, Cacciatore L, Brassetti A, Muto G, Scarpa RM, Papalia R. The Evolution of Robotic Surgery through the Machine Design Innovation. Uro. 2024 Aug 6;4(3):124-35. mdpi.com
4. Abid R, Hussein AA, Guru KA. Artificial intelligence in urology: current status and future perspectives. Urologic Clinics. 2024 Feb 1;51(1):117-30.
5. Chung G, Hinoul P, Coplan P, Yoo A. Trends in the diffusion of robotic surgery in prostate, uterus, and colorectal procedures: a retrospective population-based study. Journal of robotic surgery. 2021 Apr;15:275-91.
6. Hout M, Gurayah A, Arbelaez MC, Blachman-Braun R, Shah K, Herrmann TR, Shah HN. Incidence and risk factors for postoperative urinary incontinence after various prostate enucleation procedures: systemic review and meta-analysis of PubMed literature from 2000 to 2021. World Journal of Urology. 2022 Nov;40(11):2731-45. [HTML]
7. Asadizeidabadi A, Hosseini S, Vetshev F, Osminin S, Hosseini S. Comparison of da Vinci 5 with previous versions of da Vinci and Sina: A review. Laparoscopic, Endoscopic and Robotic Surgery. 2024 Jun 1;7(2):60-5. sciencedirect.com
8. Morrell AL, Morrell-Junior AC, Morrell AG, Mendes JM, Tustumi F, DE-OLIVEIRA-E-SILVA LG, Morrell A. The history of robotic surgery and its evolution: when illusion becomes reality. Revista do Colégio Brasileiro de Cirurgiões. 2021 Jan 13;48:e20202798. scielo.br
9. Wendler T, van Leeuwen FW, Navab N, van Oosterom MN. How molecular imaging will enable robotic precision surgery: the role of artificial intelligence, augmented reality, and navigation. European Journal of Nuclear Medicine and Molecular Imaging. 2021 Dec;48(13):4201-24. springer.com
10. Salcudean SE, Moradi H, Black DG, Navab N. Robot-assisted medical imaging: A review. Proceedings of the IEEE. 2022 Apr 13;110(7):951-67. [HTML]
11. Catchpole K, Cohen T, Alfred M, Lawton S, Kanji F, Shouhed D, Nemeth L, Anger J. Human factors integration in robotic surgery. Human Factors. 2024 Mar;66(3):683-700. nih.gov
12. Avrumova F, Sivaganesan A, Alluri RK, Vaishnav A, Qureshi S, Lebl DR. Workflow and efficiency of robotic-assisted navigation in spine surgery. HSS Journal®. 2021 Oct;17(3):302-7. nih.gov

13. Hara K, Kanda M, Kuwabara H, Kobayashi Y, Inoue T. Current status analysis of the prevalence and regional disparities of robot-assisted laparoscopic prostatectomy in Japan using diagnosis procedure combination data. Scientific Reports. 2024 Oct 22;14(1):24823. nature.com
14. Carbonara U, Srinath M, Crocerossa F, Ferro M, Cantiello F, Lucarelli G, Porpiglia F, Battaglia M, Ditonno P, Autorino R. Robot-assisted radical prostatectomy versus standard laparoscopic radical prostatectomy: an evidence-based analysis of comparative outcomes. World journal of urology. 2021 Oct 1:1-2. [HTML]
15. Narducci F, Bogart E, Hebert T, Gauthier T, Collinet P, Classe JM, Lecuru F, Delest A, Motton S, Conri V, Ferrer C. Severe perioperative morbidity after robot-assisted versus conventional laparoscopy in gynecologic oncology: results of the randomized ROBOGYN-1004 trial. Gynecologic oncology. 2020 Aug 1;158(2):382-9. [HTML]
16. Feng Q, Yuan W, Li T, Tang B, Jia B, Zhou Y, Zhang W, Zhao R, Zhang C, Cheng L, Zhang X. Robotic versus laparoscopic surgery for middle and low rectal cancer (REAL): short-term outcomes of a multicentre randomised controlled trial. The lancet Gastroenterology & hepatology. 2022 Nov 1;7(11):991-1004. researchgate.net
17. Winner Olabiyi EF, Daniel S. Robots Help with Surgery and Recovery: How machines can assist with surgery and help patients recover faster. 2023. researchgate.net
18. Bozkurt E, Sijberden JP, Hilal MA. What is the current role and what are the prospects of the robotic approach in liver surgery?. Cancers. 2022 Aug 31;14(17):4268.
19. Ayo-Farai O, Olaide BA, Maduka CP, Okongwu CC. Engineering innovations in healthcare: a review of developments in the USA. Engineering Science & Technology Journal. 2023 Dec 7;4(6):381-400. fepbl.com
20. Tariq A, Gill AY, Hussain HK. Evaluating the potential of artificial intelligence in orthopedic surgery for value-based healthcare. International Journal of Multidisciplinary Sciences and Arts. 2023 Jun 9;2(1):27-35. itscience.org

CITE AS: Ahereza Prissy. (2024). Robotic Surgery: Precision and Patient Outcomes. RESEARCH INVENTION JOURNAL OF BIOLOGICAL AND APPLIED SCIENCES 4(2):23-27. https://doi.org/10.59298/RIJBAS/2024/422327