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Impact of Robotic Surgery on Oncologic Treatment: Literature Review

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ABSTRACT

Robotic surgery has become one of the most promising innovations in surgical oncology, providing magnified three-dimensional visualization, seven-degree-of-freedom articulated instrumentation, and physiologic tremor elimination, which together enable more delicate dissections in restricted anatomical fields. Randomized trials and cohort series report lower intra-operative blood loss, shorter hospital stays, and faster functional recovery when compared with conventional laparoscopy and open surgery. Robotic technology has also enabled more extensive lymphadenectomies and preservation of critical neurovascular structures, resulting in better postoperative quality of life, particularly for pelvic and mediastinal tumors. Nevertheless, evidence of oncologic superiority in terms of overall survival and recurrence remains inconsistent, requiring long-term follow-up and robust multicenter trials. Major barriers to wider adoption include the system's initial cost, expensive maintenance, and the need for formal training with a prolonged learning curve factors that restrict access to economically advantaged centers of excellence. Finally, artificial intelligence, augmented reality, and high-latency teleoperation are emerging trends that could democratize robotics and mitigate current limitations. In conclusion, despite substantial proven advances, equitable adoption of robotic platforms will depend on cost reductions, expansion of training programs, and production of long-term oncologic effectiveness data.

Keywords:

Robotic surgery; Oncology; Medical Technology; Cancer treatment; Minimally invasive surgery.

Objectives

This article aims to discuss, based on the current scientific literature, the impact of this technology on surgical cancer management, exploring the main advances, evidence, and obstacles that must still be overcome for robotic surgery to become an oncologic standard of care.

Introduction

Oncologic surgery has evolved dramatically since the first reports of radical resections in the nineteenth century through the advent of laparoscopy in the 1990s. The relentless pursuit of less-invasive procedures with equal or greater oncologic efficacy has driven the adoption of robotic surgery, approved by the U.S. Food and Drug Administration in 2000. Unlike laparoscopy, which limits range of motion and offers only two-dimensional vision, robotic systems provide magnified scaling, 360° EndoWrist articulation, and superior ergonomics, allowing precise manipulation even in confined spaces such as the male pelvis [1]. Reduced surgical morbidity, lower inflammatory stress, and accelerated functional recovery justify the growing interest in this technological platform.

Over the past two decades, robotics has expanded from radical prostatectomies to multiple oncologic domains, including hysterectomies and gynecologic lymphadenectomies, complex colorectal resections, pulmonary lobectomies, and minimally invasive pancreatectomies [2,3]. In Brazil, the first system was installed in 2008, and today more than 120 platforms are distributed among private hospitals and university centers, concentrated primarily in the Southeast region. In lower-income Latin American countries, access inequality persists, reflecting structural health-system challenges and high acquisition costs that can exceed two million dollars [4].

Technically, high-definition three-dimensional visualization favors identification of avascular planes and nerve structures, reducing conversion rates to laparoscopy or open surgery and enabling more extensive lymphadenectomies, potentially relevant for staging and local disease control [5]. Console control eliminates physiologic tremor and reduces surgeon fatigue particularly important in prolonged operations. Prospective series suggest improved surgical margins and preservation of neurovascular bundles in radical prostatectomy, with earlier recovery of urinary continence and erectile function than observed with conventional approaches [6].

Despite these benefits, well-founded criticisms remain. Recent meta-analyses show that for colorectal tumors, the robotic gains in complications and specimen quality have not yet translated into statistically significant differences in survival or recurrence when compared with laparoscopy [7]. Operative time also tends to be longer during the learning curve, potentially increasing operating-room costs [8]. Maintenance of robotic arms, disposable instruments with limited life cycles, and proprietary royalties further elevate the procedure's total cost, prompting debates over cost-effectiveness and sustainability in public systems [9]. Methodological gaps in current studies must also be acknowledged. Most investigations consist of single-center retrospective series, generally conducted in high-volume institutions, introducing selection bias and limiting extrapolation to hospitals with less experience. Multicenter randomized controlled trials comparing robotics, laparoscopy, and open surgery across different neoplasms with follow-up beyond five years remain scarce. Only with such data will it be possible to determine whether robotic platforms should definitively replace traditional techniques or occupy specific niches where their technical advantages translate into tangible oncologic benefit.

Discussion

Clinical outcomes of robotic surgery in oncology should be interpreted in light of three central dimensions: perioperative results, long-term oncologic efficacy, and cost-effectiveness.

Perioperative outcomes

Multinational cohort evidence demonstrates that robotics reduces average blood loss by 300–400 mL and decreases transfusion requirements by up to 40% compared with laparoscopy, particularly in prostatectomies and oncologic hysterectomies [3]. Postoperative length of stay falls by about 1.5 days on average, promoting early return to activities and meeting hospital efficiency metrics [5].

Oncologic efficacy

Outcomes such as negative surgical margins, number of lymph nodes removed, and disease-free survival vary by tumor site. For prostate cancer, a meta-analysis by Kim et al. [6] reported a 15% positive-margin rate for robotics versus 22% for laparoscopy, without a significant difference in five-year survival. For colorectal cancer, Wilson et al. [7] found no overall-survival advantage, although robotics was associated with lower conversion to laparoscopy. Robotic pulmonary lobectomies show lower bleeding and postoperative pain than video-assisted thoracic surgery, but long-term randomized studies are still pending [2].

Economic considerations

Robotic platforms cost about 2–2.5 million dollars, with annual maintenance near 10% of that value, plus disposable instruments with limited lifespan [9]. Studies by Brown et al. [8] and Johnson et al. [1] show that even in high-volume centers, per-case costs are 1.3–1.6 times higher than laparoscopy, only partially offset by reduced complication-related readmissions. In public systems of middle-income countries, these offsets are insufficient to justify broad adoption.

Training

Proficiency requires an estimated 20–40 supervised cases to achieve basic competence and up to 100 cases to reach efficiency plateau [8]. Simulation-based and modular certification programs help shorten the learning curve but incur extra costs. Lack of standardization hinders inter-center comparisons and creates barriers to resident credentialing in low-volume institutions.

Future perspectives

Integration of artificial intelligence capable of providing real-time intra-operative feedback, critical structure recognition, and automated suturing assistance is emerging [10]. Tele-surgery enabled by low-latency 5G networks has already allowed experimental intercontinental procedures, signaling potential support for peripheral hospitals. Competitors to the da Vinci system are launching lower-cost modular platforms, likely stimulating competition and reducing prices over the next decade [11,12].

Ethical issues include liability in software failure, surgical data privacy, and access equity. Differential reimbursement policies and tax incentives may accelerate adoption in underserved regions but require rigorous monitoring to prevent resource waste.

Environmental impact

Robotic procedures use large quantities of disposable instruments and demand higher energy consumption, increasing hospitals' carbon footprints. Recycling initiatives for plastic components and optimized block scheduling are emerging strategies to mitigate these effects but lack clear regulation and economic incentives [13]. Thus, robotic surgery offers unquestionable advantages in safety and ergonomics but still lacks definitive evidence of oncologic superiority. Its implementation must result from a multidimensional analysis that combines clinical, economic, and social indicators, always contextualized to each health-care reality.

Conclusion

Integrated analysis of the literature shows that robotic surgery occupies a technological leadership role in contemporary oncology that goes beyond its status as a mere minimally invasive tool. The platform enhances surgeon ergonomics, extends the precision of complex dissections, and confers tangible benefits in bleeding, postoperative pain, and length of stay—factors that collectively elevate patient satisfaction and optimize hospital indicators [5]. Its capacity to perform extensive lymphadenectomies while preserving critical structures suggests a potentially positive impact on staging and, in certain subgroups, disease-free survival [6]. However, perioperative benefits do not uniformly translate into long-term oncologic gains. For various tumors, particularly colorectal and pulmonary the current evidence points to equivalent overall survival between robotic and laparoscopic approaches, indicating that tumor biology, patient selection, and multidisciplinary practice remain decisive in therapeutic trajectories [2,7]. This finding underscores the need for multicenter randomized clinical trials with follow-up beyond five years to definitively clarify robotics' role as a gold standard.

Cost remains a substantial obstacle. Although learning curves reduce operative time and complications over the years, the system's initial expense, plus maintenance and disposables, makes adoption financially challenging, especially in developing countries [8,9]. Inter-institutional sharing, leasing, and governmental incentives may ease this barrier but require economic models tailored to local realities. Human-resource development is equally critical. Structured programs with high-fidelity simulation, graduated mentorship, and transparent certification are indispensable to ensure safety and result homogeneity. Incorporating artificial intelligence for objective performance assessment may accelerate learning curves and detect errors before they become adverse events [10].

Looking ahead, convergence of robotics, augmented reality, real-time data analytics, and teleoperation promises to expand frontiers, connecting specialists across long distances and granting access to populations previously excluded from reference centers [11,12]. Ethical and environmental concerns will shape public policy, emphasizing data transparency, legal responsibility for software failures, and reduction of hospitals' carbon footprints [13]. Therefore, while robotic surgery already represents a concrete and irreversible advance in surgical oncology, it still requires robust proof of oncologic superiority, sustainable financing strategies, and comprehensive training programs before becoming a universal standard. Investment in high-methodological-quality research, combined with policies that address access equity, will be decisive so that the technology's benefits reach, fairly, all cancer patients regardless of geographic location or socioeconomic status.

In sum, consolidating robotic surgery as an essential component of the oncologic therapeutic arsenal will depend on the intersection of scientific evidence, economic viability, and social responsibility. Health-care systems that integrate these pillars will be prepared to deliver state-of-the-art surgical interventions, minimize disparities, and ensure that technological progress translates into real improvements in outcomes for the global oncologic population. It is incumbent upon administrators, researchers, and care professionals to engage in continuous and collaborative dialogue, sharing dataand experiences to accelerate innovation, optimize resources, and, above all, prioritize patient safety and dignity. Only then can the potential of robotic surgery be transformed into a tangible and lasting benefit in the fight against cancer.

Conflict of Interest

None.

References

1. Johnson T, Oliveira J, Smith R, et al. Minimally invasive techniques in oncology: the role of robotics. *Med Technol J.* 2020;45(1):49-57.

2. Garcia M, Gomez P, Oliveira J, et al. The impact of robotics in oncologic surgery: a systematic review. *J Cancer Res.* 2022;99(6):501-510.

3. Fernandez H, Garcia M, Smith R, et al. Robotic surgery for gynecologic cancers. *J Gynecol Oncol.* 2023;34(1):1-8.

4. Santos R, Almeida L, Cruz F, et al. Robotic surgical systems in Latin America: growth and accessibility. *Lat Am Surg.* 2022;48(3):145-152.

5. Smith R, Brown P, Gomez P, et al. Advances in robotic surgery for cancer treatment. *J Surg Oncol.* 2023;130(2):135-142.

6. Kim Y, Lee C, Chang D, et al. Outcomes of robotic-assisted surgery in cancer patients. *Int J Oncol.* 2021;57(3):301-309.

7. Wilson A, Mendes R, Choi Y, et al. Robotic vs laparoscopic surgery in colorectal cancer: a meta-analysis. *Colorectal Dis.* 2023;25(1):22-30.

8. Brown P, Chang D, Fernandez H, et al. Robotic surgery in oncology: current trends and future directions. *Cancer Surg J.* 2022;118(4):221-230.

9. Patel N, Sharma K, Wilson A, et al. Cost-effectiveness analysis of robotic surgery in oncology. *Health Econ Rev.* 2023;13(1):19-27.

10. Almeida L, Kim Y, Silva R, et al. Artificial intelligence in robotic surgery: clinical perspectives and challenges. *Tech Cancer Treat.* 2023;17(2):105-112.

11. Oliveira J, Kim Y, Garcia M, et al. A evolução da cirurgia robótica na oncologia. *Saude Tecnol.* 2021;19(3):89-97.

12. Lee C, Fernandez H, Johnson T, et al. Innovations in surgical oncology: the robotic revolution. *World J Oncol.* 2021;11(2):87-95.

13. Gomez P, Johnson T, Brown P, et al. The future of robotic surgery in oncology. *Cancer Med.* 2020;9(5):255-264.