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RESEARCH ARTICLE
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EVOLUTION OF ROBOTIC-ASSISTED SURGERY: A SYSTEMATIC REVIEW OF OUTCOMES IN MAJOR SURGICAL SPECIALTIES

Dr Gulshan Kumar[1], Dr Vikram Singh yadav[2*]

[1]Associate Professor SKS Hospital Medical College and Research Centre
[2*]Assistant Professor SKS Hospital Medical College and Research Centre

***Corresponding Author:** Dr Vikram Singh Yadav
*Assistant Professor SKS Hospital Medical College and Research Centre

Abstract
Robotic assisted surgery has changed modern surgical practice, increasing precision and decreasing invasiveness. In this systematic review, evaluate its evolution focusing on perioperative outcomes across major surgical specialties. The greater blood loss, shorter hospital stay, and fewer complications that robotic systems show compared to open surgery (OS) make them representative of a superior form of treatment. Overall, however, remain less conclusive than minimally invasive surgery (MIS) because the complication rates are similar and due to longer operative times. High costs, steep learning curves, and limited accessible pose key challenges in the uptake. These systems are candidates for improvement by emerging technologies, like artificial intelligence (AI), haptic feedback, and augmented reality. Overcoming these technical challenges will require cost effective, efficient solutions to bring robotic surgery further and to integrate into healthcare in an equitable way.

Keywords: Robotic-assisted surgery, Minimally invasive surgery (MIS), Surgical precision, open surgery (OS) etc.

Introduction

The field of robotic assisted surgery has emerged as a new transformative force in healthcare with developments going all the way back to the 1980s. Previous Pioneering systems such as the PUMA 560 provided a basis for subsequent innovations resulting in Minimally Invasive Procedures more precisely. In the last decade, robotic platforms have been widely found in the specialties of urology, gynecology and cardiothoracic surgery. However, robotic surgery is plagued by many both advantages such as improved ergonomics and enhanced visualization that are inherent. Include high costs, operation inefficiencies, and variable learning curves across procedures. This paper begins with a discussion about robotic assisted surgery and investigates its effects on perioperative outcomes and barriers to adoption of this technology. It discusses what innovation would allow us to do that would improve clinical utility and accessibility.

Literature review

Evolution of Robotic-Assisted Surgery: Advancements, Challenges, and Outcomes

According to the author Ashrafian *et al*, 2017. Since its inception, robotic assisted surgery has advanced tremendously thanks to technological advancements meant to make robotic assistants more precise, for patients' sake. This literature traces five generations of robotic surgical platforms, from stereotactic systems of yesterday to bioinspired and autonomous systems of tomorrow, all of which hold enormous transformative potential in medicine. The PUMA 560 was the first robotic system to show that procedures such as brain biopsies could be safely done with improved precision. These early platforms gave ways to reduce trauma, shorten hospital stay, accelerate recovery, and paved the way for minimally invasive surgery (MIS). Both of these systems introduced to soft tissue surgery revolutionized the field and were subsequently adopted by the field of urology, gynecology and cardiothoracic surgery (Karthik *et al*., 2015). But robotic surgery also faces lot of challenges. Gaps exist in the cost mitigation for adoption in widespread deployment due to high costs of acquisition, maintenance and operation. Learned curves for proficiency are procedure dependent, especially for complex surgeries, and can be steep. Its practicality in clinical environments is also limited by operational constraints, specifically, space constraints and the setup time required. Robotic surgery is based on clinical evidence indicating better reduction of complications, faster recovery times and less blood loss when compared to open methods. Nevertheless, outcomes compared to traditional MIS are not nearly as definitive (Cundy *et al*., 2018). The future of robotic systems is looked ahead to with potential future developments of advancements in visualization, haptic feedback and machine learning integration. These initiatives strive to improve surgeon decisions, patient safety and to overcome costs and accessibility issues. While still maturing, robotic assisted surgery has promise to fundamentally change the way surgery is provided across several specialties.

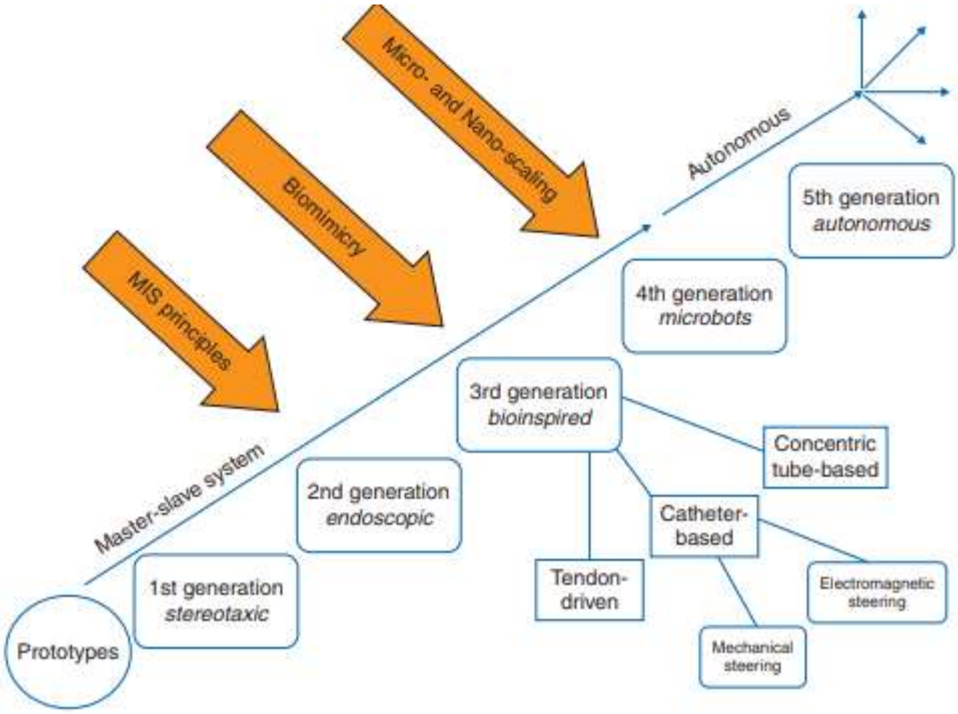

Figure 1: The evolution of five generations of surgical robotics
(Source: Ashrafian *et al*. 2017)

Robotic Surgery: Evaluating Innovation and Outcomes Over Three Decades
According to the author Tan *et al*, 2016. Three decades into the history of robotic assisted surgery, robotic precision, ergonomics, and patient outcomes have advanced greatly. To investigate its perioperative outcomes vs open surgery (OS) and conventional minimally invasive surgery (MIS) in the major surgical specialties, performed a systematic review and meta-analysis. The wireless review, which includes 108 studies and more than 14,000 patients, details some of the benefits of robotic surgery. Robotic systems had lower rates of blood loss, blood transfusions, hospitalization, and overall complication rate compared with OS. These results indicate the beneficial effect of robotic platforms in improving patient recovery and reducing perioperative risks. However, marginal

improvements in blood loss and transfusion needs are achieved at similar complication rates and length of stay as MIS, although robotic surgery does not have as much of an advantage. However, while robotic surgeries are provided with these benefits, operative times during robotic surgeries were consistently longer than those for both OS and MIS.

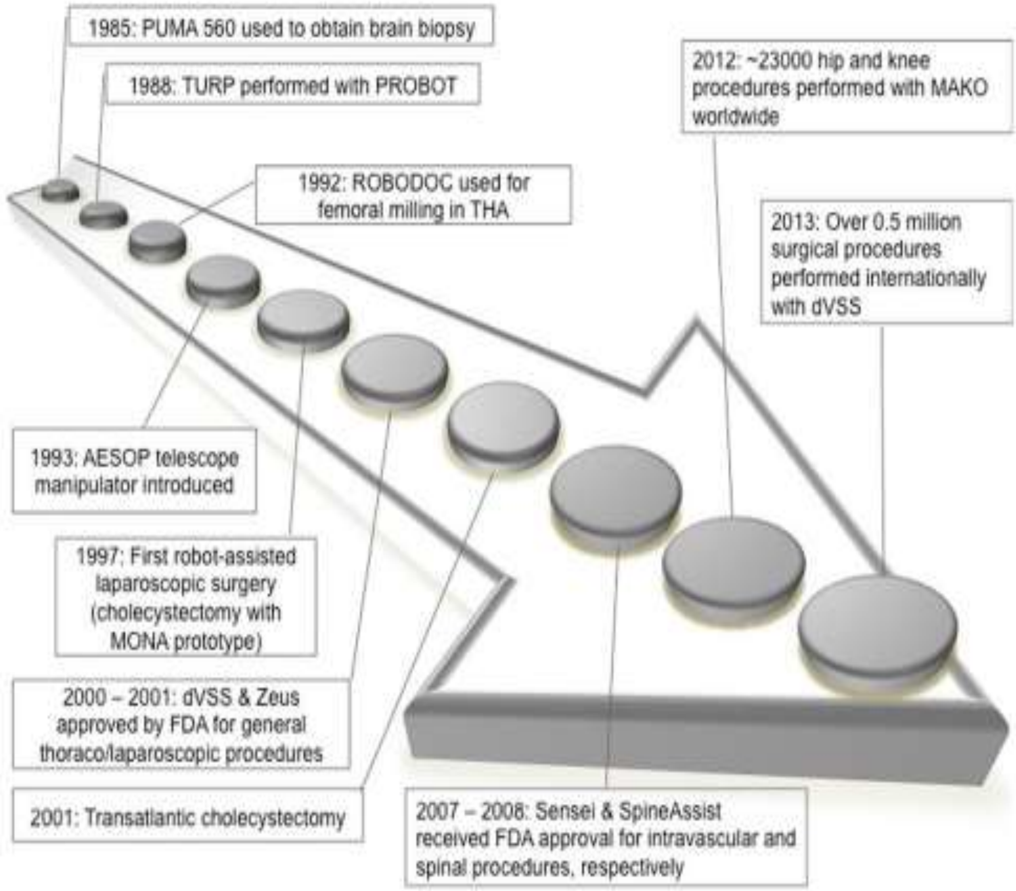

Figure 2: Timeline demonstrating selected events in the history and development of surgical robots

(Source: Tan *et al*, 2016)

The results imply that robotic systems are especially powerful in the realm of complex procedures, such as prostatectomies and gynecological procedures, where precision and minimized invasiveness are fundamental. Despite that, steep learning curves, operational inefficiencies, and high costs mean that those same challenges limit accessibility and widespread adoption. The reviewed studies were noted to have biases in randomization, blinding and reporting, methodological limitations. An analysis of randomized controlled trials (RCTs) showed inconsistencies, especially in regards to robotic surgery's robustness relative to minimally invasive surgery (MIS) in improving outcomes (Autorino *et al*., 2013). Overall, robotic surgery is a major clinical and ergonomic advance, but further justification is needed through higher quality evidence before its adoption. Broad integration into health care systems will require attaining a high degree of cost effectiveness and operational efficiency. The conclusion of this study is that the next generation of robotic platforms should be designed to lower costs, improve reliability and prove unequivocal clinical superiority over conventional methods. Because understanding why these specialized robots are practical will be crucial in guiding future robotic innovations and providing the proper strategic use of robotic technology in surgical practice, these insights are important.

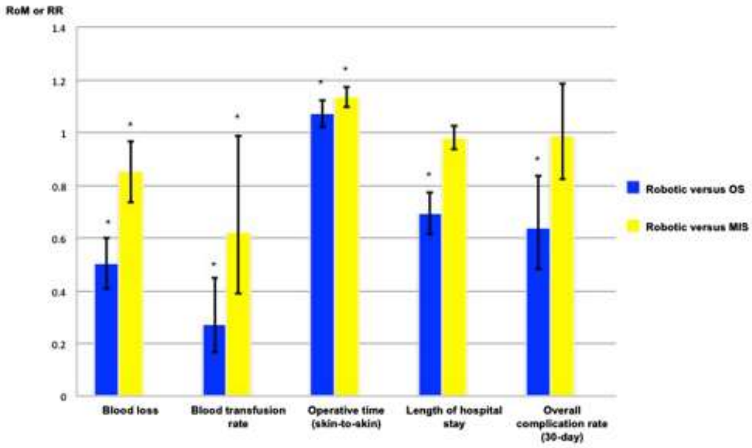

Figure 3: 5 Pooled proportional change in perioperative outcomes for robotic versus open surgery and robotic versus minimally invasive surgery

(Source: Tan *et al*, 2016)

Methods

Data collection and data processing

A systematic search was performed on electronic databases such as MEDLINE, EMBASE, PsycINFO and ClinicalTrials.gov to identify studies that assessed robotic assisted surgery outcomes. It searched publications according to 1990–2013, focusing comparative studies of perioperative variables blood loss, complication rates, operative time, hospital time, and overall outcomes (Halabi *et al*., 2013). Included were RCTs and non-randomised prospective studies doing surgical procedures where robotic approaches were reasonable alternatives to open surgery (OS) or minimally invasive surgery (MIS). Tools of established quality such as the Cochrane Risk of Bias tool were used to assess the quality of relevant articles. This exhaustive process has been important to establish the data pool as reliable and inclusive so that a real assessment of the clinical impact of robotic surgery could be made.

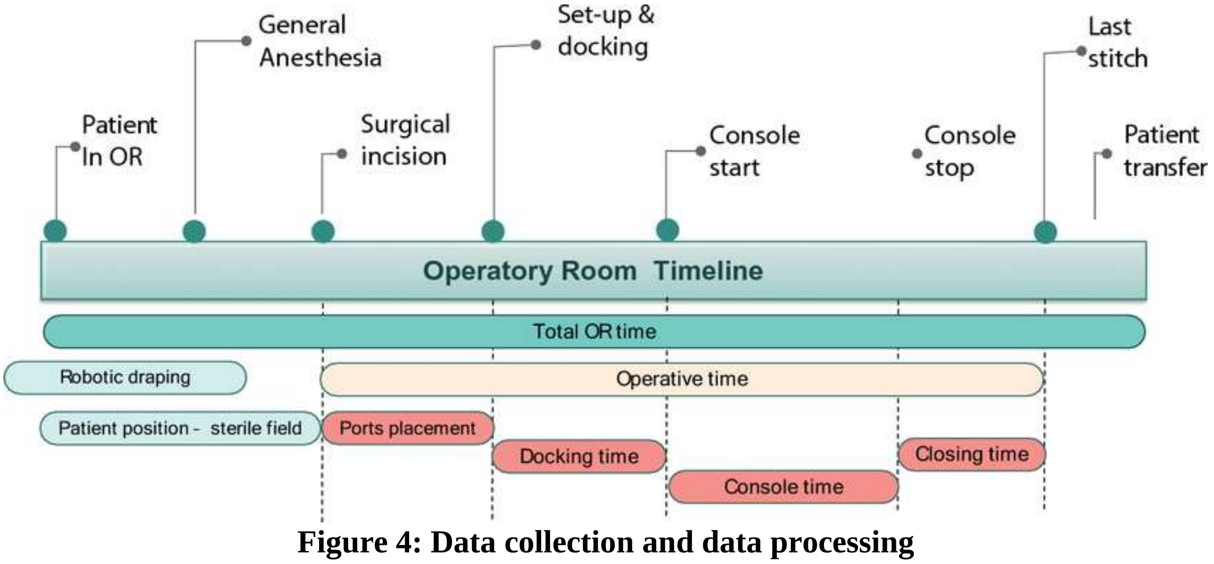

Figure 4: Data collection and data processing

(Source: https://www.researchgate.net/)

Designing of Machine Learning Models

The data was collected, analyzed, and then drawn into machine learning models to predict which robotic assisted surgery will be effective, and which will not. These models of the perioperative period examined key perioperative outcomes (blood loss, complication rates, operative times) for different surgical specialties. The algorithms were trained using the familiar procedures of supervised learning to recognize patterns in surgical performance as well as in patient recovery trends (Shah *et al*., 2014). Variable such as surgical type, patient demographic's and robot assisted interventions were added to improve the models to have predictive accuracy. These insights were intended to identify areas in which robotic surgery differs from conventional surgery, that is, where robotic surgery was shown to be uniquely advantageous, or where its limitations were highlighted. With future datasets, the models would allow the role of robotic platforms in the clinical setting to be assessed and accommodate the evolving role of robotic platforms.

Implementation and Deployment

Accuracy and reliability for robotic surgery outcomes analysis of these predictive models were tested and validated. Data were gathered from a raft of studies in order to reduce the effect of bias and inconsistencies through incorporating statistical methods like meta and sensitivity tries. Based on these models, resource allocation strategies were formulated to maximize deployment of robotic systems in healthcare settings (Schreuder *et al*., 2012). This was the phase of deployment where we integrated machine learning predictions into the clinical workflow in an effort to improve the reasoning of healthcare providers, streamline the rollout of robotic surgery, and enforce the enforcement of the laws of evidence. While this approach generated insights that were at the same time actionable and compliant with healthcare delivery goals, its application could not yet be practical.

Figure 5: Implementation and Deployment
(Source: https://jesit.springeropen.com/)

Result

Predictive Analytics in Sales and Demand

It also informs about the hike in demand for robotic assisted surgery system due to the more complex procedures like prostatectomy and gynecological surgery. Predictive analytics models were used to evaluate adoption trends and exhibited that robotic platforms are preferred when specialties demand precision and minimal invasive treatments, information relevant to market dynamics and strategy tailoring direction to the manufacturers (Sivaraman *et al*., 2015). Key findings included how to deal with high demand surgical areas considering the cost, training and operational barriers. It further shows that robotic adoption is correlated with better clinical outcomes, and more investment in robotic technology is needed to keep up with growing demand for robots in a variety of surgical specialties worldwide.

Innovation Strategies for Inventory Management and Replenishment

The purpose of this thesis was to utilize advanced forecasting tools to assist in the optimal allocation and utilization in robotic systems within healthcare facilities. Parameters and costs are evaluated prior to and during resource assignment to optimize resource use, reduce instances of over or undertainty of resources, and enable efficient resource planning that considers the procedure type, patient demographic, and system availability. As a result, this approach lessens financial waste and affords surgical teams with quick access to the required technology(Moglia *et al*., 2016). Robotic platform maintenance and updating are also a priority of inventory management strategies, which are combined with maximizing operational efficiency. But these innovations in inventory management aren't just saving costs; increasing the scalability of robotic systems, allowing the technology to expand to smaller healthcare providers who would be hardpressed to afford it, diffusing this technology to more and more patient demand.

Redesigning the Lines of Logistics and Supply

Improved logistics framework is identified as a key for successful deployment and maintenance of robotic systems in healthcare. Thanks to these frameworks, robotic platform, component, and accessory supply chains are streamlined to allow robotic platforms, components and accessories to be delivered on time to surgical facilities (Crawford and Dwyer, 2018). The integration of predictive analytics with logistics management enables healthcare providers to predict system requirements, and to anticipate shortages or delays. Additionally, the broader acceptance of robotic assisted surgery, especially in remote or resource limited areas, is also supported by enhanced supply chain efficiency. Furthermore, robust maintenance protocols built in to logistics strategies enhance system reliability and minimize downtime and improve surgical outcomes. These advancements make it easy to incorporate robotic platforms into the clinical workflow thereby increasing the use of robotic systems in all surgical subspecialty.

Discussion

There is clear evidence that OS has benefits of robotic surgery for surgical precision, less blood, and better patient recovery. Nevertheless, its superiority in comparing to MIS is much less important as to the complication rates and prolonged operative times. Despite these challenges, the adoption has been limited by steep learning curves, high costs, and sometimes limited accessibility(Tan *et al*., 2016). Furthermore, it is frequently the case that all clinical studies are biased. There is a need to close these gaps with robust, high quality, research and operational innovations. Future systems should lower the training effort and cost, and integrate seamlessly throughout clinical workflows. Discuss the importance of using AI driven tools and improved ergonomics to get the most out of robotic systems.

Future Directions

Current limitations must be addressed on future robotic platforms, which are affordable, efficient, and have advanced capabilities. Improve visualization through augmented reality and improving surgeon performance through AI for real-time decision making. Tactile sensitivity, as well as precision and safety during procedures should be provided via haptic feedback systems, which should be prioritized. Expanding the training programs is needed to overcome the steep learning curve, which requires surgeons to get proficient quickly(Ashrafian *et al*., 2017) Moreover, it should be research on evidence based improvements with clear superiority over MIS to be adopted in many heterogeneous healthcare systems worldwide.

Conclusion

Robotic assisted surgery is an innovative surgical procedure that represents a breakthrough development in surgical care, improving precision and reducing the trouble, the prices, and the recoveries. However, high costs, insufficient accessibility and uncertain impact over MIS must be overcome. Future developments should concentrate on software cost reduction, additional technological developments , and additional improvements to training systems. Whether these systems can be demonstrated to provide clear benefits — clinical and operational — to the broader community will determine whether these are adopted. While robotic surgery continues to evolve, it's a journey which is poised to change the future of healthcare and provide transformative solutions for any range of surgical specialties while delivering improved patient outcomes and optimized surgical work flow.

Reference list

Journal

1. Ashrafian, H., Clancy, O., Grover, V. and Darzi, A., 2017. The evolution of robotic surgery: surgical and anaesthetic aspects. *BJA: British Journal of Anaesthesia*, *119*(suppl_1), pp.i72-i84.
2. Tan, A., Ashrafian, H., Scott, A.J., Mason, S.E., Harling, L., Athanasiou, T. and Darzi, A., 2016. Robotic surgery: disruptive innovation or unfulfilled promise? A systematic review and meta-analysis of the first 30 years. *Surgical endoscopy*, *30*, pp.4330-4352.
3. Crawford, D.L. and Dwyer, A.M., 2018. Evolution and literature review of robotic general surgery resident training 2002–2018. *Updates in Surgery*, *70*, pp.363-368.
4. Moglia, A., Ferrari, V., Morelli, L., Ferrari, M., Mosca, F. and Cuschieri, A., 2016. A systematic review of virtual reality simulators for robot-assisted surgery. *European urology*, *69*(6), pp.1065-1080.
5. Sivaraman, A., Sanchez-Salas, R., Prapotnich, D., Barret, E., Mombet, A., Cathala, N., Rozet, F., Galiano, M. and Cathelineau, X., 2015. Robotics in urological surgery: evolution, current status and future perspectives. *Actas Urológicas Españolas (English Edition)*, *39*(7), pp.435-441.
6. Schreuder, H.W., Wolswijk, R., Zweemer, R.P., Schijven, M.P. and Verheijen, R.H., 2012. Training and learning robotic surgery, time for a more structured approach: a systematic review. *BJOG: An International Journal of Obstetrics & Gynaecology*, *119*(2), pp.137-149.
7. Shah, J., Vyas, A. and Vyas, D., 2014. The history of robotics in surgical specialties. *American journal of robotic surgery*, *1*(1), pp.12-20.
8. Halabi, W.J., Kang, C.Y., Jafari, M.D., Nguyen, V.Q., Carmichael, J.C., Mills, S., Stamos, M.J. and Pigazzi, A., 2013. Robotic-assisted colorectal surgery in the United States: a nationwide analysis of trends and outcomes. *World journal of surgery*, *37*, pp.2782-2790.
9. Autorino, R., Kaouk, J.H., Stolzenburg, J.U., Gill, I.S., Mottrie, A., Tewari, A. and Cadeddu, J.A., 2013. Current status and future directions of robotic single-site surgery: a systematic review. *European urology*, *63*(2), pp.266-280.
10. Karthik, K., Colegate-Stone, T., Dasgupta, P., Tavakkolizadeh, A. and Sinha, J., 2015. Robotic surgery in trauma and orthopaedics: a systematic review. *The bone & joint journal*, *97*(3), pp.292-299.
11. Cundy, T.P., Harley, S.J., Marcus, H.J., Hughes-Hallett, A. and Khurana, S., 2018. Global trends in paediatric robot-assisted urological surgery: a bibliometric and progressive scholarly acceptance analysis. *Journal of Robotic Surgery*, *12*, pp.109-115.