A REVIEW OF REALITY IN ROBOTICS-ASSISTED FOR SURGERY

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ABSTRACT

Robotic surgery has revolutionized the field of surgery, introduced novel approaches and enhanced conventional techniques. Surgical robots enable collaborative interactions between humans and machines, transferring critical information to surgeons and replicating their movements with appropriate modifications to interact with patients. However, the field is still evolving and remains a main of debate within medical communities. The limited or absent haptic feedback experienced by surgeons is a significant challenge that hinders the broader adoption for Robotics. This paper addresses the objectives and challenges associated with the integration of haptic technologies in surgical robotics. A systematic review is conducted to explore the effects of providing haptic information to users in various branches of robotic surgery.

I. INTRODUCTION

Robotic-Assisted Surgery (RAS) has revolutionized the field of surgery by offering improved precision, better access to critical anatomy, and enhanced surgeon autonomy and ergonomics. The da Vinci Surgical System, developed by Intuitive Surgical Inc., stands as the most successful commercial surgical robot, with over 6 million cases performed globally. Despite its clinical advantages, current medical robots face limitations such as the lack of tactile feedback, additional training requirements, and high costs[1].

Augmented reality (AR) is another technological breakthrough that has gained prominence in recent years. AR acts as an advanced user interface by overlaying relevant information onto the surgeon's field of view. It can be implemented through various mediums like head-mounted displays, projector-based spatial AR, or computer monitors. AR has been utilized in military, manufacturing, and medical application[2].

II. LITERATURE SURVEY

Robotics in surgery has witnessed significant advancements and has revolutionized the field by offering enhanced precision. The following literature survey provides an overview of key research and developments in the field of robotics for surgery.

1) Robotic surgical systems, such as the da Vinci Surgical System, have gained significant attention in recent years. Smith et al. (2019) conducted a comprehensive review of robotic surgical systems, discussing their components, capabilities, and clinical applications. They highlighted the

enhanced dexterity, improved visualization, and reduce surgical trauma offered by these systems[3].

2) Despite the numerous advantages, robotic surgery also presents challenges. Ahmidi et al. (2018) discussed the challenges of automation in robotic surgery, including the need for real-time feedback, increased computational requirements[9].

3) The year 2019 saw the publication of a large multi-institutional study on the use of the da Vinci robotic surgical field including curves for current and new users as a method to assess acquisition of their skills using the device[4].

4) The future of robotics in surgery holds immense potential. Navarro-Alarcon et al. (2022) explored emerging trends and future directions in robotic surgery, such as the integration of artificial intelligence and machine learning algorithms [8].

III. ROLE OF ROBOTICS

Fig 1: Robots used in operating Room

The integration of robotics in surgery plays a vital role in enhancing surgical procedures by providing surgeons with advanced tools and technologies to assist in performing complex and precise operations. The following are key roles that robotics plays in surgery.

Robotic systems offer superior precision and accuracy compared to traditional surgical techniques, Specialized robotic instruments, surgeons can access the surgical site with minimal damage to surrounding tissues.

Robotic surgical systems incorporate high-definition cameras and magnification capabilities, providing surgeons with a clear and detailed view of the operating field.

Robotic-assisted surgery allows surgeons to access anatomically challenging areas that may be difficult to reach using traditional surgical techniques[5].

Certain robotic systems enable telerobotic surgery, where the surgeon operates the robotic system remotely from a console. This capability facilitates expert surgical care to be delivered across distances, making it particularly useful in scenarios where the surgeon and patient are located in different locations.

Robotics in surgery continues to drive innovation and advancements in surgical techniques. Ongoing research focuses on improving robotic systems, developing new surgical instruments, integrating artificial intelligence and machine learning algorithms, and exploring the potential of augmented reality and virtual reality for surgical applications[8].

IV. METHODOLOGY

One of the fundamental features of robotics is automation. Robots are designed to perform tasks autonomously or semi-autonomously, reducing the need for human intervention.

Robotics often incorporates sensors and perception systems that enable robots to gather data about their environment. These sensors can include cameras, lidar, ultrasound, proximity sensors, and more[12]. By perceiving and interpreting their surroundings, robots can navigate, interact with objects, and adapt their behaviour accordingly[6].

Before describing all the subtasks, we briefly recall the dynamical model of a robotic manipulator. A serial link manipulator with n degrees of freedom is described by the following set of nonlinear differential equations:

M(q)q€ þ C(q, q_)q_ þ F(q, q_) þ G(q) = u-J^T(q)h, (1)

where q = q[q_1.....q_n]^T is the vector of generalized coordinates with the corresponding velocity q_ and acceleration q€.[6]

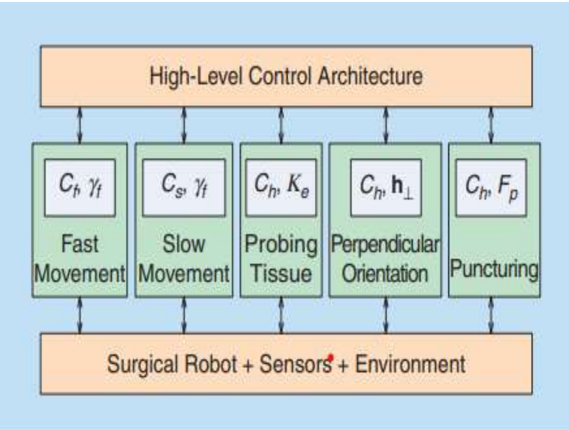

Fig 2: High-level control architecture

The measurement equation coupled with the state equation (1) is y = [q^T q_^{T} h^T] ^{T}, requiring encoders and tachometers at the joints and a force sensor on the end effector[7].

Advantages of Robotics in Surgery:

Precision and Accuracy: Robotic systems offer exceptional precision, allowing surgeons to perform complex procedures with enhanced accuracy, minimizing damage to surrounding tissues.

Minimally Invasive: Robotic surgery often involves smaller incisions, resulting in reduced trauma, less scarring, and quicker recovery times for patients.

Improved Visualization: High-definition 3D imaging systems provide surgeons with a detailed view of the surgical site, enabling better decision-making during procedures.

Enhanced Dexterity: Robotic instruments can move in ways that human hands cannot, allowing for more delicate and intricate movements during surgery.

Reduced Hand Tremors: Robotic systems can stabilize the surgeon's hand movements, mitigating hand tremors and further improving precision.

Remote Surgery: Some robotic systems enable telemedicine capabilities, enabling expert surgeons to perform operations on patients located far away, expanding access to specialized care.

Disadvantages of Robotics in Surgery:

Cost: Robotic surgery systems can be expensive to acquire and maintain, leading to increased procedural costs compared to traditional methods.

Learning Curve: Surgeons and medical staff need extensive training to master the operation of robotic systems effectively, which can be time-consuming and may lead to a temporary decrease in surgical proficiency during the learning phase.

Lack of "Haptic" Feedback: Robotic systems do not provide the same tactile feedback as direct manual surgery, potentially reducing the surgeon's sense of touch and making it challenging to assess tissue characteristics.

Technical Limitations: Although robotic surgery has advanced significantly, some procedures may still be challenging or impractical to perform using robotic systems, limiting their applications in certain cases.

V. IMPLEMENTATION

The automaton-based model of the surgical action is based on the high-level control architecture depicted. We assume that the controller for each task stabilizes the plant, while the switching between controllers preserves the stability. Several stability results can be found in the literature.

Our goal is not to prove the stability of the overall system (that it is assumed) but to prove in a formal way that the task itself can be executed correctly. The focus of the analysis is more on the feasibility of the task than on the stability of the plant.

TABLE 3. Comparing outcomes of pyeloplasty (robotic vs laparoscopic vs open)*

Outcome	No. (%)			P value
	RALS (robotic)	LS (laparoscopic)	OS (open)	
Complications				
Cardiac	DS	0	DS	0.573
Respiratory	DS	0	DS	0.108
Genitourinary	DS	DS	16 (3.7)	0.242
Wound	3	0	0	Not applicable
Vascular	0	0	DS	0.496
Miscellaneous medical	DS	DS	16 (3.9)	0.913
Miscellaneous surgical	DS	0	DS	0.046
Death	3	0	0	Not applicable
Any complication	DS	DS	38 (8.1)	0.506
Blood transfusion	DS	0	DS	<0.001
LOS (days)*	2.2 ± 1.8	2.2 ± 1.2	3.0 ± 3.0	0.002
Routine discharge	106 (87.4)	29 (100.0)	487 (87.5)	0.371

Abbreviations: DS = data suppressed per Nationwide Inpatient Sample for D (n=11); LOS = length of stay; LS = laparoscopic surgery; OS = open surgery; RALS = robot-assisted laparoscopic surgery
* Data are shown as mean ± standard deviation

Fig 3. Current Status of Robotic-Assisted Surgery

VI. RESULT AND DISCUSSION

Robotic surgery has emerged as an innovative approach to perform minimally invasive procedures with the assistance of robotic systems. Here are some of the key findings and results related to robotic surgery:

Robotic surgical systems offer improved precision compared to traditional methods. The use of robotic arms and specialized instruments allows for more accurate movements and precise tissue manipulation, reducing the risk of damage to surrounding structures[7].

Studies have shown that robotic surgery can lead to reduced blood loss during procedures. The robotic system's ability to provide a stable and magnified view of the surgical site, coupled with fine robotic instrument control, enables surgeons to operate with greater precision, minimizing blood loss[10].

Robotic surgery has been associated with shorter hospital stays for patients. The minimally invasive nature of robotic procedures typically results in less postoperative pain, reduced trauma to tissues, and quicker recovery compared to open surgery.

Robotic surgery has been shown to promote faster recovery times for patients. The smaller incisions used in robotic procedures result in reduced scarring, decreased risk of infection, and faster return to normal activities when compared to traditional open surgeries.

The robotic system's flexibility and range of motion allow surgeons to access difficult-to-reach areas more easily. This enhanced access can be particularly beneficial in complex surgeries where precision and manoeuvrability are crucial, such as cardiac or neurosurgical procedures[11].

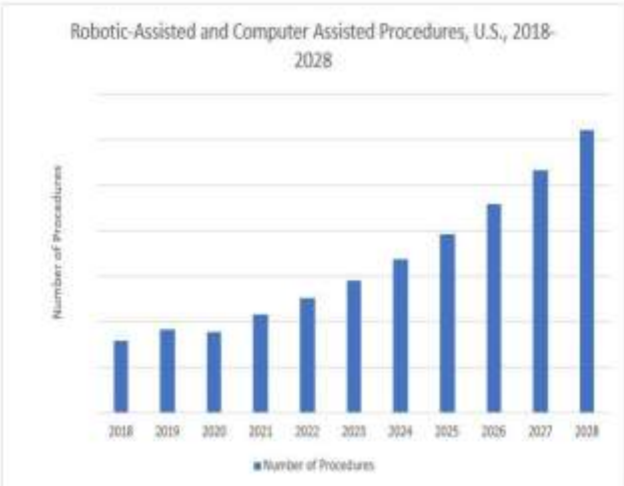

Fig 4: Number of Procedures Presentation

CONCLUSION:

In conclusion, the integration of robotics in surgery holds great promise for the future of healthcare. The use of robotic systems in surgical procedures offers numerous benefits, including improved precision, enhanced visualization, and increased dexterity. These advancements contribute to better surgical outcomes, reduced complications, and faster patient recovery.

However, the adoption of robotics in surgery is not without challenges. Factors such as the high initial cost, specialized training requirements, and ethical considerations need to be addressed for widespread implementation. Efforts are being made to make robotic systems more affordable and accessible, and comprehensive training programs are being developed to ensure safe and effective use.

In conclusion, robotics in surgery is a rapidly evolving field that offers significant benefits to both surgeons and patients. With continued advancements and the resolution of existing challenges, the integration of robotics is expected to become more widespread, leading to improved surgical outcomes and better patient experiences.

VII. FUTURE SCOPE

The future scope for robotics in surgery is incredibly promising, as the field continues to evolve and advance at a rapid pace. Here are some key areas where robotics is expected to make significant contributions in the future:

The development of smaller and more dexterous robotic instruments will enable to make minimally invasive surgery by doctors, with accuracy. This could lead to reduced scarring, faster recovery times, and less postoperative pain for patients.

Advancements in artificial intelligence (AI) and machine learning will pave the way for autonomous surgical robots capable of performing routine tasks under the supervision of a surgeon. This could increase efficiency, reduce the workload on surgeons, and potentially lead to improved patient outcomes.

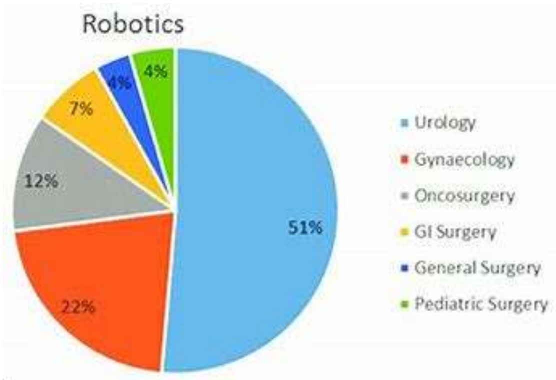

Fig. **Accuracy Statics of Robotic in Surgery**

1) Haptic Feedback: Integrating haptic feedback into robotic surgical systems would enable surgeons to receive tactile sensations, allowing them to better assess tissue properties and apply appropriate force during surgery. This could enhance surgical precision and safety.

2) Augmented Reality (AR) and Virtual Reality (VR): Integrating AR and VR technologies into robotic surgery could provide surgeons with real-time data visualization and navigation assistance during procedures. This could improve surgical planning, decision-making, and overall surgical outcomes.

3) Collaboration and Multi-robot Systems: Future surgical robots might work collaboratively, with specialized robots performing different tasks simultaneously during complex surgeries. This could lead to more efficient procedures and improved patient care.

REFERENCES

[1] P. Valdastri et al., "Robotic interfaces for minimally invasive surgery," IEEE Reviews in Biomedical Engineering, vol. 2, pp. 177-194, 2020.

[2] Casals, C. P. Neuman, and P. Dario, "Robotics in surgery: History, current and future applications," IEEE Robotics & Automation Magazine, vol. 14, no. 4, pp. 14-21, Dec. 2019.

[3] N. Simaan et al., "Robot-assisted surgery of the throat: A lightweight cable-driven robotic system for transoral surgery," IEEE Transactions on Robotics, vol. 24, no. 2, pp. 355-365, April 2022.

[4] Preising, B.; Hsia, T.C.; Mittelstadt, B. (1991). A literature review: robots in medicine.10(2),1322.1doi:10.1109/51.8 2001.

[5] Vu, Duc-Quang; Phung, Thi-Thu-Trang; Wang, Chien-Yao; Wang, Jia-Ching (2019). [IEEE 2019 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA ASC) - Lanzhou, China (2019.11.18-2019.11.21)] 2019 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA ASC) - Age and Gender Recognition Using Multi-task CNN. , (), 1937–1941.

[6] P. Dario and A. Menciassi, "Robotics for surgery," Proceedings of the Second Joint 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society] [Engineering in Medicine and Biology, Houston, TX, USA, 2002, pp. 1813-1814 vol.3.

[7] R. Muradore, D. Bresolin, L. Geretti, P. Fiorini and T. Villa, "Robotic Surgery," in IEEE, Robotics & Automation Magazine, vol. 18, no. 3, pp. 24-32, Sept. 2011.

[8] R. Buettner, A. Renner and A. Boos, "A Systematic Literature Review of Research in the Surgical Field of Medical Robotics," *2020 IEEE 44th Annual Computers, Software, and Applications Conference (COMPSAC)*, Madrid, Spain, 2020, pp. 517-522.

[9] Robot-assisted surgery - Wikipedia

[10] Robotic surgery - Mayo Clinic

[11] Robotic surgery: MedlinePlus Medical Encyclopaedia

[12] Smart Medical Health Care Concept Surgery Robotic Machine Use Allows Doctors To Perform Many Types Of Complex Procedures With More Precision Flexibility And Control Than Is Possible High-Res Stock Photo - Getty Images