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The Impact of Medical Robots in Improving the Efficiency of Health

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Introduction

In recent times, healthcare systems globally have encountered the challenge of increasing expenditures while striving to enhance outcomes, both in terms of clinical and economic performance, as well as the overall health of the population (Topol, 2019). Concomitant with these obstacles are a variety of technologies that offer the potential for an enhanced public sector through digital services that aid patients, enhance the system's cost-effectiveness, and optimize working conditions for healthcare and social care practitioners. Significant progress in the adoption and proliferation of automation, fueled by technological advances in computation, sensing, networking, and communications, has propelled this process. Artificial intelligence (AI) and machine learning (ML), currently regarded as the most significant general-purpose technologies, have expanded the domains of automation to include knowledge, care work, and service operations, in addition to mechanized labor and industrial robotics (Vallès-Peris & Domènech, 2020).

As the fields of artificial intelligence (AI) and human-robot collaboration (HRC) converge, more and more robots are finding their way into healthcare settings like hospitals (Heerink et al., 2016). Natural language processing, social interaction, abstract problem-solving, perceptual recognition, and other once human-only tasks may soon be within the realm of possibilities, thanks to developments in ML.

Robots are tangible entities that possess the ability to perceive and react to their surroundings by means of physical engagement. They exhibit variability in their visual appearance, sensory capacities, and level of autonomy. They have the ability to manage materials that pose a danger to humans, can perform repetitive tasks with exceptional accuracy, and are resistant to psychological fatigue.

As healthcare expenses account for about 10% of the worldwide gross domestic product (GDP) (Chang et al., 2019), the significance of digital innovation is growing in order to decrease expenses and enhance results. Robotics is a field of digital innovation that has the potential to greatly influence healthcare.

The application of robotics in the medical field is not a novel notion. One of the earliest documented healthcare applications of robotics occurred during the 1980s, when technological advancements enabled the use of robots to delineate the path of a brain biopsy (Okamura et al., 2010). Subsequently, remarkable advancements in technology have had a beneficial effect on the functionalities of robotics. Presently, robotic systems are implemented to automate pharmacy operations, hospital logistics, and productivity, among other applications.

1. **Robot**

Czech "robota" means "slave," "servant," or "forced labor," which is where the English word "robot" originates. Nevertheless, advancements in mechatronics and artificial intelligence (AI) are crucial to the contemporary view of robots. To be more precise, robots are physical embodiments of mechanical intelligence that can move around in their physical environment and carry out complicated tasks. This

means that most people do not consider gadgets that do not have any kind of mechanical action to be robots. Robots can detect their surroundings, compute to make decisions, and execute coordinated mechatronic operations in the physical world. This is based on this definition of autonomy or semi-autonomy.

The two most common ways that robots are categorized are as industrial and service robots. Service robots are utilized in personal, home, and professional contexts, whilst industrial robots are utilized in automation of manufacturing processes (Lee, 2021). What we call "health-care robots" are really just service robots that have been programmed to assist with many aspects of healthcare, such as patient diagnosis and treatment, assistive technology for the disabled, rehabilitation, and general patient care and medical intervention.

More than eight million robots are currently operational in various parts of the globe. Due to factors such as changing demographics, healthcare worker shortages, and the desire to improve treatment while reducing costs, the use of healthcare robots is anticipated to increase, even though this area is still in its early phases of development and experimentation (Cone & Lambert, 2019).

2. Global Drivers of Robotics in Healthcare

The use of robots into healthcare has significantly altered the medical field by providing inventive solutions to meet the changing requirements of patients and healthcare professionals. Medical robotics has become a fundamental aspect of modern healthcare, serving many purposes such as aiding surgeons in intricate surgeries and delivering individualized care to elderly populations. The acceptance and advancement of robotic technologies in healthcare settings globally are influenced by numerous socioeconomic and technological factors.

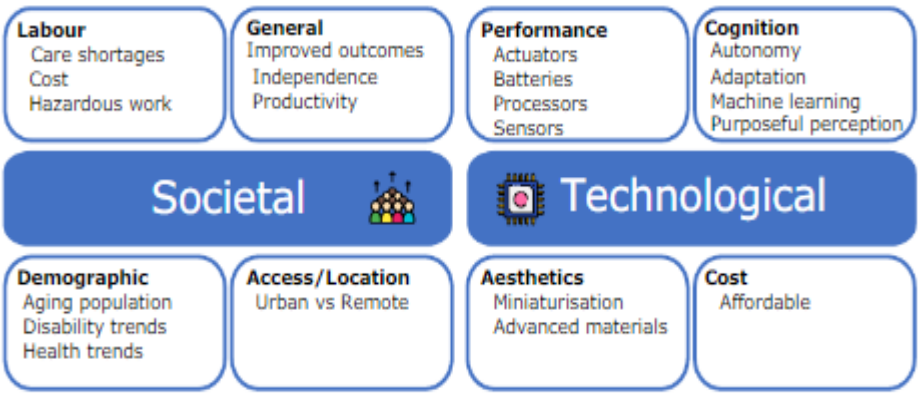

Figure (1): Main Drivers Driving the Adoption of Robots in the Healthcare

2.1.Societal Drivers

- Labor Shortages

Healthcare systems globally are increasingly worried about labor shortages caused by factors such as a growing elderly population and rising healthcare needs. The demand on healthcare workers is clearly apparent, as the scarcity of surgeons, nurses, and caretakers is becoming increasingly noticeable. Medical robots have developed as a practical alternative to enhance the current healthcare staff. Medical robots relieve healthcare personnel of their responsibilities by automating repetitive duties, such as delivering medication and monitoring patients. This enables healthcare staff to dedicate their attention to more intricate and crucial parts of patient care. In addition, surgical robots aid doctors in carrying out complex procedures with accuracy and effectiveness, reducing the negative effects of a shortage of medical personnel on surgical results.

- Access and Location

Obtaining high-quality healthcare services continues to be difficult in distant and neglected regions across the globe. Geographical limitations frequently restrict the accessibility of specialist medical knowledge, diagnostics, and therapies in certain areas. Medical robotics, namely telemedicine and mobile robots, are transforming healthcare delivery by effectively addressing these obstacles. Telemedicine platforms provide remote consultations, diagnostics, and even procedures, linking patients in rural or distant regions with professionals situated elsewhere (Avgousti et al., 2016). Moreover, mobile robots that are equipped with diagnostic instruments and telepresence capabilities have the ability to traverse difficult terrains in order to reach patients requiring assistance. This enables them to deliver prompt and life-saving therapies, regardless of the patients' geographical location.

- General Expectations

With the progress of medical research and technology, the demands of society for healthcare are increasing. Both patients and caregivers anticipate having access to state-of-the-art therapies, customized care choices, and improved results. Medical robotics fulfills these expectations by providing cutting-edge solutions that enhance the quality and effectiveness of healthcare services (Javaid et al., 2021). Robotic-assisted procedures reduce invasiveness and speed up recovery, while robotic companions offer social connection and emotional support, so improving the overall patient experience. Furthermore, the incorporation of robotics into healthcare workflows simplifies procedures, decreases waiting periods, and guarantees more consistent and dependable provision of care, in accordance with the changing demands of contemporary healthcare consumers.

- Demographic Changes

Changes in population demographics, such as the increasing number of older individuals and evolving family dynamics, have a substantial influence on healthcare requirements and how it is provided. The increasing number of aged adults in need of long-term care and support has led to a growing demand for healthcare services specifically designed for aging populations. Medical robotics is essential for tackling these demographic concerns by providing assistive gadgets, rehabilitative therapies, and remote monitoring systems that are specifically tailored for aged patients. These robotic devices empower elderly folks to preserve their autonomy, enhance their standard of living, and reduce the workload on caregivers and healthcare facilities, thus addressing the changing requirements of aging societies.

2.2.Technological Drivers

- Cost Reduction

The high cost of robotic systems and components has hindered their widespread implementation in the healthcare sector. Nevertheless, the progress in technology and the ability to produce on a larger scale are reducing expenses, thereby making medical robots more reasonably priced and available to healthcare professionals across the globe (Aguiar Noury et al., 2021). Advancements in manufacturing techniques, materials, and the integration of components have resulted in cost reductions without sacrificing the performance or dependability. Consequently, healthcare institutions now have the ability to allocate resources towards robotic technology in order to increase patient care, optimize operational efficiency, and attain superior clinical outcomes, all while adhering to budgetary limitations.

- Cognition and Artificial Intelligence:

The fusion of artificial intelligence (AI) and robotics is transforming the healthcare industry by augmenting the cognitive powers of robots. Artificial intelligence algorithms empower robots to analyze intricate medical data, render well-informed judgments, and adjust their actions in response to immediate feedback. AI-powered robotic systems in diagnostics provide unprecedented precision in analyzing medical pictures, assisting in early disease detection and treatment planning (Roski et al., 2019). In addition, AI-powered robotic helpers improve patient care by customizing treatment plans, forecasting negative occurrences, and optimizing therapeutic treatments. Through the utilization of artificial intelligence, medical robots are revolutionizing the provision of healthcare, introducing a new era characterized by precise medical treatments and individualized patient care.

- Performance Enhancement

Progressive developments in robotics technology have resulted in notable enhancements in performance parameters such as velocity, accuracy, and dependability. Contemporary robotic systems have the ability to perform intricate tasks with exceptional precision and effectiveness, surpassing human talents in

specific areas. Robotic-assisted treatments in surgical robotics provide improved dexterity, stability, and visualization, leading to superior surgical outcomes and decreased postoperative problems. Robotic rehabilitation devices offer specialized therapy that is customized to meet the specific needs of each patient, resulting in faster recovery and enhanced functional outcomes. The advancement of robotic technology has the potential to greatly improve healthcare performance in a wide range of specialties and applications.

- Aesthetics and Patient Experience

The design and aesthetics of robotic systems are essential in influencing the patient's experience and adoption of these technology. The adoption of sleek and non-intimidating robotic designs, along with user-friendly interfaces, enhances the patient experience during robotic-assisted healthcare procedures. This, in turn, promotes trust and confidence in the technology. Whether it is a surgical robot in the operating room or a robotic companion at a care facility, the visual appeal is important in establishing a pleasant and inviting atmosphere for patients. Moreover, the utilization of robotic systems that prioritize the well-being and security of patients, incorporating ergonomic characteristics and intelligent sensors, effectively enhances the overall patient experience. This, in turn, encourages patients to adhere more effectively to their treatment plans and ultimately leads to improved clinical outcomes.

3. Classification of Robots in Healthcare

Robots may be categorized into three distinct classifications according to their spatial orientation in relation to the patient's body. Assistive systems, insertibles, and accessories are included. Depending on the task at hand, the degree of autonomy exhibited by each of these robots differs. Certain machines are engineered with the capability of self-learning cognition in order to aid in behavioral therapy (Alla & Pazos, 2019).

3.1.Insertibles

- Microbots: Microbots are minuscule robotic devices specifically engineered for insertion into the human body to carry out a range of medicinal functions at the microscopic level. These devices have the ability to traverse within the bloodstream or other body fluids in order to administer medications, carry out precise therapy, or aid in diagnostic procedures such as imaging or biopsies.
- Tethered Robots: Tethered robots are robotic devices that are placed into the body and operated remotely through a physical connection such as a tether or wire. These robots are frequently employed in minimally invasive surgical procedures, where doctors can direct them to execute accurate movements and interventions inside the body.

3.2.Wearables

- Robotic Prostheses: Robotic prostheses are wearable devices specifically created to substitute or enhance body components that are absent or defective, such as limbs or joints. These gadgets utilize robotic components and sensors to imitate natural movements, enhancing users' mobility and functionality.
- Exoskeletons: Robotic exoskeletons are wearable apparatuses that offer external reinforcement and aid to the user's physique. These devices comprise robotic articulations and actuators affixed to a wearable structure, allowing users to ambulate, maintain an upright posture, or engage in other tasks with enhanced force and steadiness.

3.3.Assistive Systems

- Mobile Manipulators: Mobile manipulators are autonomous robotic systems that are equipped with both manipulator arms and mobile bases, enabling them to navigate and engage with objects in their surrounding environment. These robots are frequently employed in medical environments to facilitate duties such as conveying supplies, dispensing medication, or supporting patient care.
- Patient Simulators: Patient simulators are mechanized models employed for medical instruction and simulation drills. These technologies have the capability to replicate different physiological reactions and medical situations, enabling healthcare workers to engage in procedural practice, increase their abilities, and improve patient safety within a controlled setting.
- Mental & Behavioral Healthcare Robots: Robots specifically engineered to offer aid and support in mental health and behavioral therapy environments. These robots can interact with patients by engaging them in activities, offering companionship, or aiding clinicians in delivering therapeutic therapies.
- Physical Support Task Robots: These robots are specifically created to offer physical aid and assistance to people who have limitations or disabilities in their ability to move. These robots can assist with activities like lifting, transferring, or placing patients, thereby improving their autonomy and overall well-being.
- Service Robots: Service robots are highly adaptable robotic systems specifically engineered to carry out a diverse array of duties inside healthcare environments. These robots may consist of automated carts for moving supplies, sanitation robots for up keeping cleanliness, or receptionist robots for welcoming and aiding visitors. Service robots enhance efficiency and productivity in healthcare institutions by reallocating human resources to more specialized duties.

4. Medical Robots and their Role in Healthcare

Medical robots are advanced instruments created to aid healthcare practitioners in carrying out a wide

range of medical duties, including surgical operations, patient care, and rehabilitation. These robots are outfitted with sophisticated sensors, actuators, and computerized systems that allow for accurate and regulated movements, as well as instantaneous data processing. Medical robots play a diverse and ever-changing role in healthcare as technology progresses. Medical robots have several important roles and purposes, which include:

- Surgical Assistance: Surgical robots, like the da Vinci Surgical System, aid surgeons in doing minimally invasive treatments with improved accuracy and command (Haidegger et al., 2022). These robots are equipped with robotic arms that have surgical equipment and a high-definition camera. This enables surgeons to do operations with more precision by making smaller incisions. Surgical robots are frequently utilized in medical disciplines such as urology, gynaecology, and general surgery.
- Rehabilitation and Therapy: Robotic devices are employed in rehabilitation environments to aid patients in their recovery from injuries or surgeries, as well as individuals with limited mobility. Robotic exoskeletons offer assistance and support to aid patients in recovering strength, mobility, and coordination. Robotic therapy equipment also aid in doing repetitive workouts and tasks to enhance the process of healing and enhance functional outcomes.
- Diagnostic Imaging and Interventions: Medical robots are essential in performing diagnostic imaging procedures and interventions, such as magnetic resonance imaging (MRI) and computed tomography (CT) scans (Erin et al., 2020). Robotic systems are employed to accurately manipulate patients and medical devices during imaging examinations, guaranteeing the highest level of image quality and precision. In addition, robots aid in performing minimally invasive treatments, such as biopsies and catheter-based therapies, by offering accurate guidance and control.
- Patient Care and Assistance: Companion robots and robotic carers offer aid and help to patients in healthcare facilities, rehabilitation centers, and home environments. These robots provide companionship, medicine and appointment reminders, as well as aid with daily activities such as bathing, dressing, and meal preparation. Robotic carers additionally oversee vital signs and notify healthcare personnel of any alterations in a patient's state, thereby improving patient safety and well-being.

Medical robots are crucial in improving healthcare outcomes by increasing accuracy, effectiveness, and safety in medical procedures. They also offer individualized care and assistance to patients in various healthcare environments. With the continuous advancement of technology, the prospective uses of medical robots in healthcare are anticipated to grow, leading to a further transformation in the way medical care is provided and enhancing patient results.

5. Impact of Medical Robots on Improving Healthcare Efficiency and Enhancing Patient Experience

Due to the increasing demand for top-notch healthcare services, healthcare providers are rapidly adopting robots to make operations more efficient, make better use of resources, and enhance patient outcomes.

A key benefit of robotics in healthcare is its capacity to improve efficiency in multiple areas of medical practice. According to (Reddy et al., 2023) surgical robots, such as those mentioned, empower surgeons to execute intricate surgeries with unmatched accuracy and command, leading to decreased operation durations, minimized blood loss, and expedited patient recuperation. In addition, the implementation of robotic automation in hospital operations, including tasks such as drug administration, sterilization, and inventory management, reduces the occurrence of mistakes made by humans (Sarker et al., 2021), decreases operational expenses, and allows healthcare personnel to dedicate more time and attention to providing excellent patient care.

In addition to improving productivity, robotics in healthcare are crucial for boosting the overall patient experience. According to (Van der Loos et al., 2016) Robots play a role in ensuring a smooth and customized experience for patients as soon as they enter a healthcare institution. Robotic companions offer company and assistance, reducing anxiety and loneliness, especially for patients undergoing extended therapies or rehabilitation. Surgical robots in the operating room provide minimally invasive operations, resulting in shorter hospital stays, decreased post-operative discomfort, and enhanced overall satisfaction (Cheng & Rezac, 2018). Furthermore, robots equipped with telepresence capabilities provide remote consultations and virtual visits, guaranteeing the uninterrupted provision of healthcare and enhancing accessibility for patients residing in distant or neglected regions.

The influence of robotics in healthcare beyond mere technological progress; it profoundly revolutionizes the manner in which healthcare is provided and encountered. Robotics not only improve hospital efficiency and enhance the patient experience, but also lead to better clinical outcomes and empower patients, carers, and healthcare providers. The ongoing advancement of robotics technology holds immense potential for enhancing healthcare delivery and improving patient care. This progress offers the possibility of a future where innovation and compassion come together to redefine the benchmarks of excellence in healthcare.

6. Robotic Applications in Surgical Specialties

6.1.Laparoscopic Procedures

- Robotic-Assisted Laparoscopic Surgery: Robotic systems, like the da Vinci Surgical System, are commonly employed in laparoscopic procedures in several medical fields, such as urology, gynaecology, and general surgery (Koh et al., 2018). Some examples of surgical procedures are robotic-assisted prostatectomy for treating prostate cancer, robotic hysterectomy for addressing gynaecological issues, and robotic cholecystectomy for removing the gallbladder.

6.2.Orthopedic Surgeries

- Robotic-Assisted Knee Replacement: Robotic technologies are being used more and more in knee replacement surgeries to improve accuracy and the positioning of implants. Surgeons utilize robotic assistance to enhance the precision of bone cuts, ensure proper balance of soft tissues, and achieve ideal alignment, resulting in enhanced outcomes and increased longevity of the implants.
- Robotic-Assisted Spine Surgery: Robots are utilized in spine surgery to aid doctors in conducting treatments such as spinal fusion and vertebral decompression. Robotic guidance facilitates the exact positioning of pedicle screws, precise bone resection, and ideal alignment, hence decreasing the likelihood of problems and enhancing patient recuperation (D'Souza et al., 2019).

6.3.Neurosurgery

- Robotic-Assisted Cranial Surgery: Neurosurgeons utilize robotic equipment to assist them in carrying out complex cranial surgeries, including tumour removal and epilepsy surgery. Robotic devices possess exceptional accuracy and skill, enabling them to remove tissue with precision and minimize harm to other structures. This results in enhanced patient outcomes and less morbidity.
- Deep Brain Stimulation (DBS) Surgery: DBS surgery frequently employs robotic help to treat movement disorders like Parkinson's disease (Dallapiazza et al., 2018). Robotic guidance enables precise positioning of electrodes in targeted areas of the brain, maximizing the effectiveness of therapy and reducing the likelihood of problems.

6.4.Cardiac Surgery

- Robotic-Assisted Coronary Artery Bypass Surgery: Cardiac surgeons are aided by robotic equipment in carrying out minimally invasive coronary artery bypass grafting (CABG) surgeries (Koulaouzidis et al, 2023). Robotic devices facilitate accurate transplantation of blood vessels onto the heart, diminishing the requirement for sternotomy and cardiopulmonary bypass, and leading to expedited recuperation and decreased postoperative discomfort for patients.
- Robotic-Assisted Mitral Valve Repair: Robotic assistance is utilized in mitral valve repair surgeries to facilitate precise and intricate repairs to the cardiac valve. Robotic assistance improves the ability to see and control the valve apparatus, enabling accurate stitching and repair of the valve leaflets, chordae tendineae, and annulus. This leads to better valve function and long-term results.

7. The Challenges Associated with Implementation of Medical Robots

The technical difficulty associated with implementing medical robots is one of the main challenges. Medical robots frequently include sophisticated technology such as artificial intelligence, computer

vision, and intricate robotic systems. Specialized knowledge and resources are necessary to ensure the smooth integration of new technologies into the existing healthcare infrastructure. Healthcare organisations must allocate resources to train their staff and improve their infrastructure in order to properly support the operation and upkeep of medical robots.

According to (Lawrie et al., 2022) another notable obstacle is the financial burden of procuring and up keeping medical robots. The initial capital outlay for acquiring robotic systems can be significant, and the continuous costs associated with maintenance, updates, and training further contribute to the financial strain. Healthcare providers must thoroughly assess the cost-effectiveness of using medical robots and take into account issues such as return on investment, payment models, and long-term viability.

Ensuring patient acceptance and safety of medical robots are crucial factors to consider when implementing them. Patients may harbor apprehensions regarding the implementation of robotic technology in healthcare, encompassing anxieties about potential blunders, violations of privacy, and the erosion of human interaction. Healthcare providers are obligated to offer patients with information regarding the advantages and drawbacks of medical robots, as well as to address any concerns they may have, in order to encourage acceptance and establish trust. In addition, guaranteeing the secure functioning of medical robots necessitates strong safety regulations, risk management techniques, and ongoing monitoring to avert unfavorable incidents and safeguard the safety of patients.

Conclusion

The incorporation of medical robots into healthcare systems has fundamentally transformed the provision of services, significantly influencing both effectiveness and patient satisfaction. A notable advantage is the accuracy and uniformity they provide throughout medical treatments. Robots have the ability to perform activities with very few mistakes, unlike humans. This improves the precision of diagnosis and treatments. By employing precision, the occurrence of medical errors is minimized and patients are guaranteed to receive the most optimal care.

Moreover, medical robots enhance the efficiency of healthcare facilities. By implementing automation in operations such as medicine administration, sterilization, and data management, healthcare workers are able to allocate more time to the intricate and specialized parts of patient care. This efficient workflow results in reduced waiting times, optimized scheduling, and ultimately, increased overall efficiency in healthcare institutions.

The incorporation of medical robots signifies a substantial leap in the progress of healthcare services. These technology advancements are revolutionizing healthcare delivery by increasing efficiency and

improving the patient experience. As a result, they are leading to improved outcomes and higher satisfaction levels for both patients and healthcare practitioners.

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