REVIEW ARTICLE

Exploring the Impact of Robotic Technologies on Healthcare Delivery and Patient Care

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Abstract

Modern technological developments have made it easier for scientists and researchers to improve healthcare services. Modern technologies have been widely incorporated into the creation and usage of a wide range of medical devices, including those for testing, monitoring, diagnosis, and treatment. With the latest developments in robotics, healthcare has the potential to benefit from robot support. In hospitals, for rehabilitation and walking aid, in the care of the elderly, children, and people with disabilities, and in other healthcare settings, robotic systems are frequently implemented. This survey report discusses the most current developments in robotic technology used in the healthcare industry. The goal of using assistive robotic devices in health care is to free up nursing staff time. To enable a goal-oriented and participative development of assistive robotic systems of care, differentiated and literature-based results on present application possibilities, technological developments, and empirical findings are required. Modern research on hospital care, assistive, rehabilitative, and walking assistance robots is covered in length in this study. The open issues that healthcare robots must overcome to be accepted by society are also covered in this study. This study aimed to increase the availability, acceptability, and quality of robotics in health care by bringing the topic to a broader audience.

Key words: Healthcare delivery, patient care, robotics

INTRODUCTION

Robots are physically embodied systems with the ability to interact physically with their environment to sense and respond to it. Their level of autonomy, sensory abilities, and visual appearance can all differ. They are resistant to psychological wear and tear, can perform repetitive tasks with extreme precision, and can handle materials that pose a risk to humans.[1] Over 10% of the world's gross domestic product is going toward health care, and digital innovation is becoming more crucial to lowering costs and enhancing results. One digital innovation field that has the potential to significantly affect health care is robotics. In many different contexts, including homes, offices, schools, and more, robots can help and aid humans.[2] Although it is not a novel idea, one use for robots is in healthcare. A robotic arm that interfaced with a computed tomography (CT) scanner was utilized for a CT-guided brain tumor biopsy in 1985, marking the first recorded instance of a robot-assisted surgical procedure.[3] Over the years, technological advancements have made significant progress, which has improved robot capabilities. Despite these advancements, a major barrier toward adopting robots in health care is the lack of exposure and understanding of these technologies. Health care robots should prioritize helping patients and clinicians to gain more acceptance. This study defines the uses of robots in health care and well-being using data gathered from a variety of sources. To outline the primary prospects for informing future advancements, the major goal is to address the obstacles and prerequisites for the deployment of robots in the healthcare industry.[4] The article aimed to educate a broader readership about the use of robotics in health care. The word "robota" originates in Czech and means "slave," "servant," or "forced labor."

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Received: 17-12-2024
Revised: 06-03-2026
Accepted: 18-03-2026

However, the way that people view robots today is largely dependent on advancements in mechatronics and artificial intelligence (AI). Robots are defined more precisely as mechanically embodied, AI agents that can move around in their physical environment and carry out intricate activities.[5] This indicates that gadgets that do not have a motor are not typically thought of as robots. According to this, robots can normally sense their surroundings, process information to make decisions, and coordinate mechatronic activities in the real world. These are the three tasks that they can execute either fully or partially independently. The specifics of these three elements differ among robots, but most of them repeatedly go through this cycle of sensing, cognition, and action. The two classes of robots that are most frequently mentioned are industrial and service robots. Service robots are employed in home, professional, and industrial contexts, while industrial robots are utilized in factory automation. The healthcare robots are service robots used to assist in the delivery of healthcare services, such as disease diagnosis and treatment, assistance with impaired individuals' functioning, patient care, and medical intervention.[6] The primary purpose of industrial robots was to automate tedious, hazardous, and dirty tasks without human involvement. Robots have been employed in the delivery of food and medications, cleaning of rooms, examination and treatment of suspected patients, and protection of staff members from viral exposure. Robotics and AI for future health care will only serve to reinforce current dominant discourses and power relations if we concentrate only on citizen accountability and potential high-tech company proposals to increase efficiency and effectiveness.[4] Instead, they will contribute to opening debates by proposing disruptive models to address the care crisis and the demographic challenge. The field of medical diagnosis, treatment approaches, and patient care has changed dramatically in recent years due to the introduction of AI into health care. Numerous ethical issues are raised by this paradigm change, which calls for serious analysis. The ethical ramifications and potential future developments of integrating AI technologies into health care systems are discussed in the article.

TYPES OF ROBOTS IN HEALTHCARE DELIVERY [ILLUSTRATED IN FIGURE 1]

Radiotherapy robots

Robotic radiosurgery systems allow for real-time tumor tracking and adaptive radiation delivery, which is especially useful for treating tumors in sensitive or difficult-to-reach areas. The integration of robotics with imaging technologies and AI integration has improved treatment planning and clinical outcomes, making robotic radiotherapy a promising approach in personalized cancer care. These robotic systems are designed to target tumors with high precision while minimizing damage to surrounding healthy tissues. Real-time tumor tracking and adaptive radiation treatment are made possible by technologies such as robotic radiosurgery devices, which are especially helpful for treating cancers in delicate locations. Radiotherapy robots also improve patient comfort and lower treatment mistakes due to patient movement.[7]

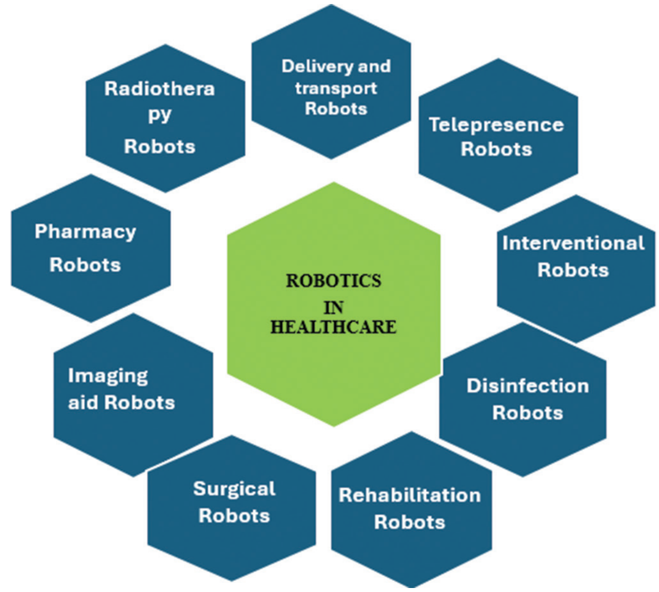

Figure 1: Types of robots in healthcare delivery

Telepresence robots

One essential feature of the telepresence robotic collective is its ability to allow people to use the robot to create a remote presence (RP). A variety of tasks, such as conducting remote ward visits, offering remote surgical mentorship, and enabling remote histology slide inspection, may be accomplished with the employment of robots. The most common robotic systems were RP robots, specifically those made by In Touch Technologies in the United States and Double Robotics in the same country. The double robot is a mobile, self-governing platform with a visual interface and two wheels. Robotic systems for visits to surgical wards in rural areas with consultant surgeons present, then contrasted this experience with standard ward procedures.[8]

Interventional robots

In contrast to their surgical counterparts, these robots are designed to support the intervention process, which encompasses a range of medical procedures such as percutaneous coronary intervention, neuroendovascular intervention, and ablation in the setting of atrial fibrillation. These tools have a wide range of potential applications, such as stent implantation and catheter guidance. The Niobe System, manufactured by Stereotaxis in the US, and the Hansen Sensei Robotic Catheter device, manufactured by Hansen Medical in the US, were the two robotic systems that were most frequently referenced. Corpath's systems

(GRX and 200), produced by Corinda in the USA, were also highlighted. The Niobe system can precisely move the catheter thanks to magnetically controlled mechanics.[9]

Pharmacy robots

A group of artificial beings has been created specifically to support the administration and delivery of pharmaceutical services. This includes the procedures for compounding, dispensing, and storing medications. To reduce errors and potential hazards to operators, a robotic system could be utilized to assist in the formulation of cytotoxic drugs. The BD Rowa™ Vmax automated system is made to store and administer medications in response to user requests.[10]

Imaging aid robots

The unique ability of the robots in this category to assist in the performance of imaging operations in a variety of medical areas has led to their employment. Robotic camera handlers are used in neurosurgery, where they are used in conjunction with robotic microscopes and transcranial magnetic stimulation robots. Two robotic camera controllers that are frequently brought up are Solo assist® (AKTORmed, Germany) and Freehand® (Freehand, UK). There are several ways to operate robotic camera handlers, including using voice commands and a joystick.[11]

Surgical robots

Surgical robots are widely used in specialities such as urology, gynecology, cardiology, and orthopedics. The use of the Intuitive Surgical da Vinci Surgical System in prostatectomy procedures has shown reduced post-operative complications and shorter recovery periods compared to conventional open surgery.[12] Surgical robots have revolutionized health care by improving the precision, flexibility, and control of surgical procedures. The surgeons can execute minimally invasive procedures with the aid of robotic technologies more accurately, with smaller incisions, less blood loss, and quicker patient recovery. Through high-definition, three-dimensional imaging, robotic-assisted surgery also enhances visibility and allows surgeons to execute intricate procedures with increased stability and dexterity.[13]

Rehabilitation robots

The use of appropriate and scientific rehabilitation techniques is crucial to a patient's capacity to regain motor function. A unique class of robots known as rehabilitation robots is made specifically to assist people who are recovering from physical disabilities. It has been previously mentioned that physiotherapy aids patients in regaining as many of their natural motor abilities as possible. Physiotherapists can get help from rehabilitation robots when their patients are recovering. Therapists who utilize rehabilitation robots are better at improving gross motor abilities. The robots can assist patients with tedious tasks and gather sensor data for study. By doing so, the therapist may more effectively adapt the rehabilitation procedure to the unique needs of each patient. This research categorizes rehabilitation robots into two groups: upper-limb and lower-limb rehabilitation robots.[14]

Assistive robots

Assistance robots offer three types of support: mobility, manipulation, and rehabilitation. Patients who have problems with hand and arm function are assisted by manipulating robots. Robotic arms fitted with grippers are frequently made to carry out certain tasks, including feeding, cleaning, picking up objects, and opening doors. Based on a Wheelchair-Mounted Robotic Arm, numerous assistive robotic devices have been developed. The FRIEND system, an intelligent manipulator fitted on a wheelchair, is an example of an assistive robotic system. The FRIEND program has been around for four generations.[15] The first three generations of the program were devoted to helping persons who were quadriplegics with ADLs such as eating and drinking, whereas the fourth generation of the program supported these people in everyday settings. Progress is being made on robots that help with semi-automated patient lifting. RIBA and Robear are made expressly to assist in lifting and moving a bedridden patient from their bed to a wheelchair. Other robotic assistance devices for patients and workers include the Quirubot, a robotic scrub nurse, and the Robot Bathtub, a device that bathes a person while they are in a lying position. The surgical treatment is dangerous due to its intrusive nature.[16]

Social robots

In the healthcare industry, social robots are being used to offer emotional support, companionship, patient monitoring, and help with therapeutic and rehabilitation activities. These robots are especially helpful for patients with cognitive or psychological disorders, elderly people, and children because they can lessen feelings of social isolation, loneliness, and anxiety. They can also help healthcare professionals by supporting patient communication, medication reminders, and routine caregiving tasks. Several case studies have shown their positive effects in clinical settings. Social robots are being utilized in health care to offer companionship, emotional support, patient monitoring, and help with therapeutic and rehabilitative tasks. Because they lessen feelings of loneliness, anxiety, and social isolation, these robots are especially helpful for people with cognitive or psychological impairments, youngsters, and the elderly. The therapeutic robot PARO has been widely used in elderly care and dementia management, where studies reported improvements in emotional well-being and reductions in stress and agitation among patients.[17] Similarly, the humanoid robot Pepper has been utilized in hospitals and rehabilitation centers to enhance patient engagement, provide information, and support social interaction.[18]

Teleoperated robots

Also known as telerobotics, it is regarded as a subset of telehealth. Long-distance delivery of specialized healthcare services is the ultimate objective. Specialists can be virtually transported by telerobotics to places without access to medical facilities or professionals. Since the start of the COVID-19 pandemic, telerobotics has gained significant relevance, mostly because of the growing need for contactless health care.[19] Surgery, therapy, and diagnosis may all be carried out remotely thanks to telerobotics. A human operator uses wired and/or wireless communication networks to remotely control the actions of robots in a teleoperated robot, also known as a telerobot.[20] Most remotely operated robots have a restricted range of capabilities, are task-oriented, and exhibit semi-autonomy. Telerobotic systems are conceptually divided into two distinct sites, even though the physical distance between them may be minimal. The delivery of remote services when there is a considerable distance between the two sites, that is, when they are not in the same building, is referred to as telerobotics.[21]

Disinfection robots

Disinfection is one of the many current areas of infectious disease management that could be improved by the integration of robotics. The employment of robots to disinfect clinical areas such as wards at hospitals or outpatient clinics could be beneficial. The group includes two studies that evaluated the performance of two robotic systems: Light Strike™ (Xenex, USA) and Ultra-Violet Disinfection Robot® (Clean Room Solutions). Both systems disinfect rooms using ultraviolet (UV) light; the ultraviolet disinfection robot (UVD-R) may move independently. Astrid *et al*. compared UVD-R with conventional manual disinfection techniques to determine how effective UVD-R is at disinfecting areas in hospital outpatient clinics.[22] Conventional systems rely on a stationary gear that frequently needs human supervision and care. Autonomous or movable UV robots can increase the employability of these contraptions. They are more self-sufficient devices that can increase the efficiency of disinfection processes while using less labor.[23]

Delivery and transport robots

The idea of using robots to move items between locations is a feasible one. The research included a trial that looked at using a delivery robot within an intensive care unit (ICU). The TUG automated system of delivery is a robotic device created by Aethon in the United States that is intended to move pharmaceuticals from the pharmacy department to the ICU without the need for human assistance.[24] Even though they have similar benefits, autonomous aerial drones and autonomous delivery robots (ADRs) have different operational advantages and downsides. However, ADRs outperform unmanned aerial vehicles. For example, Jennings and Figliozzi have observed that ADRs have a longer working range, more compartments, and a larger cargo capacity.[25] These characteristics make up for their comparatively slower speeds by enabling multiple deliveries to be made in a single journey. Similarly, even though both drones and ADRs help lower transportation-related carbon emissions, it is important to remember that drones use 4–10 times as much energy as electric ground vehicles (especially when it comes to ADRs in high to medium wind factors).[26]

THE FUTURE OF ROBOTICS IN HEALTH CARE

Numerous academic studies have been conducted on surgical robots, mobility and rehabilitation robots, and telepresence robots in the healthcare industry. It is important to note, nevertheless, that not all types of healthcare robots have received the same degree of scholarly attention. Future studies should focus on examining the potential applications and benefits of various robot types, including delivery and transport robots, imaging assistance robots, socially helpful robots, radiation robots, interventional robots, and pharmacy robots. Further research is necessary to assess the cost-effectiveness, safety, and efficacy of various robot kinds in health care.[27] Comparative studies evaluating the performance of different robot types are also necessary. Robots should be able to serve the healthcare personnel independently in more well-defined jobs involving minimal human intervention or interaction. New developments in the air transportation of drugs and pathology samples should be anticipated. Finally, significant advancements in micro- and nano-robots should be anticipated in the next 10–15 years, opening the door for this technology to help with localized drug delivery or microsurgeries.[28] In the healthcare industry, introducing new technologies is disruptive. As far as we currently know, not enough research has been done on how robots might eventually affect people. Other social robots were employed for urine testing in cancer patients, monitoring and assessing therapy procedures, and entering therapy treatments into a database.

CONCLUSION

It is critical to guarantee dependable performance and customizability, as well as to consider the potential societal impact to assure the smooth integration of robots in healthcare settings. For robots to function safely and successfully in the unstructured and unpredictable real world, reliable performance is essential. It will be necessary for customizable robots to carry out a wide range of jobs in novel environments and while collaborating with a diverse range of individuals. Robots will have a significant impact on society since they could affect how well patients receive health care and how well caregivers perform their jobs, and there may be privacy issues that need to be resolved. It is challenging to integrate modern robotic technology into health care. However, massively successful technological disruptions can be highly successful if they are approached with the right approach. Robots in health care must first be proven to be safe, dependable, and user-friendly through prototype and experimental systems before being commercialized. It is necessary to consider specific metrics for system performance and cost-effectiveness. It is necessary to conduct feasibility, impact, and economic assessments to ensure usability and acceptance. Acceptance of robots is higher when they assist hospital staff in improving care delivery, as opposed to displacing or isolating them. Widespread robot adoption is unlikely to occur until positive long-term effects are demonstrated. Robots are becoming more common in many locations and specializations because of the rising amount of evidence supporting their usage in the healthcare industry.

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Source of Support: Nil. **Conflicts of Interest:** None declared.