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Balancing Act: A Critical Review of Healthcare Robotics - Navigating Benefits and Risks

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Abstract — **The research paper examines robotics' application in healthcare critically, highlighting both its benefits and drawbacks. Examining the use of many robots, ranging from surgical instruments to assistive technology, we investigate the influence of innovative technologies during the COVID-19 era. To provide insights into the evolving landscape of healthcare robotics, emphasizing the need for a balanced approach in their integration. Despite the fact that robots are being used in healthcare, it will take some time before this technology is widely adopted. This study project's primary objective is to provide some clarity on the same. Emphasize the value of robots in healthcare and their benefits, which include improved treatment and lower long-term expenditures.**

I. INTRODUCTION

Since late 2019, Coronavirus (COVID-19) became a pandemic spreading and affecting millions of people worldwide. This critical health situation posed a life threatening encounter to the safety and health of the general public around the globe as well as, to the health care systems. A viral pandemic that affected millions of people was the traditional issue that the global society faced as a result of the coronavirus outbreak. This is a critical time to search for novel strategies and technology to stop the COVID-19 virus from spreading, particularly given the rising number of COVID-19 positive cases and the overburdened healthcare system.[1]. The most ubiquitous of all the possible uses appears to be the humanoid robot that routinely fetches a tumbler of water for the elderly. A World Health Organization (WHO) research states that between 2000 and 2018, healthcare spending climbed by $8.3 trillion, or 10% of the world's gross domestic product (GDP). This statement looked at health-care spending between 2000 and 2018 in more than 190 nations. A multitude of issues hindered healthcare delivery in hospitals and clinics during the early 2020 COVID-19 epidemic, jeopardizing the provision of essential services. [2].

The outburst of growth in technology not only results in the increase in efficiency of the current technology in use, but also the invention of many new technologies that is possible by utilizing the research and development done in the fields like that of imaging technology.

One of such technology is that of robots. They can put into r At last, the technology that scientists have long researched and created is beginning to manifest itself before our very eyes. They can put into reality countless acts and services that one can imagine, with the precision of a skilled human professional and with utmost quality too. Due to these traits in the field of robotics, it is very habitual of us human beings to utilize them in the field of medicine and especially in surgery and rehabilitation. The Da Vinci Surgical robot system is one amazing robot that is now being employed in the medical profession. This robot has been meticulously designed and assembled for endoscopic procedures within the body. This robot's movements are accurate enough to reach body areas that require great care. Therefore, it is employed in medicine and has successfully conducted numerous procedures on human

One of the many benefits of employing a robot in surgical procedures is that they make in use the highest possible degree of precision, which humans can barely reach even after years of practice, which only a few human professionals can keep up with. Robot hands don’t shake, they don’t sweat that could cause a slip, and they can make or adapt their arms as small and as flexible as possible as the need arises to complete the task at hand. It also employs a series of sensors, actuators and imaging technologies , which allow it to see , sense , and move it’s fingers accordingly, which is certainly impossible to achieve my a medical professional [3].

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II.METHADOLOGY

Stakeholder interviews, case studies, technical evaluations, ethical concerns, and literature reviews can all be combined to provide researchers with a thorough grasp of the challenges associated with integrating robotics in healthcare. The examination gains depth with the addition of a cost-benefit analysis and a comparative analysis with standard healthcare procedures. The value of both qualitative and quantitative data, which enable an in-depth knowledge of the topic.

The applications of medical robots in the sector of healthcare are chosen to discuss the effectiveness of applying robots in healthcare. The articles which are chosen in this review study are different medical robot applications within the Engaging with important parties such as developers, regulators, patients, and medical specialists ensures that different points of view are included and improves the healthcare sector. The applications are robotics laparoscopy, logistics robots, sterilization robots, vital sign robots, robotics in radiosurgery, therapeutic robots and robotics operating theatre. The selection of robotics is based on research papers and commercial products[2].

The survey consisted of two parts. The first included qualitative interviews with healthcare workers to measure their understanding of robots and capacity to use them successfully. The second stage used a quantitative method, with a questionnaire survey.

III. LITERATURE REVIEW

Medical robotics is considered to have a huge value in healthcare in regards of health, social, and economic benefits. Robotics can provide aid for a significant proportion of patients, especially for patients with certain needs such as amputees, paralyzed patients, and people with cognitive or mental disabilities[1]

Due to the significant risks to healthcare specialists in particular the surgeons during COVID-19, some surgical and medical societies proposed safety rules to be undertaken during performing surgical procedures in the current pandemic situation. To decrease the spread of communicable diseases, robots can be incorporated into the activities carried at surgical wards during the stay of the patients. Such applications are driving the request[4]

In cardiac surgery, the use of robotics had reduced the time of operations as well as risks and postoperative complications. Additionally, social robotics may be a challenging department being created having the capability of checking and persuading the patients. The development of the therapeutic and healthcare mechanical technology showcase is promising and is expanding each year [5]

A paper published by Sergio D. Sierra Marín et al presented clinicians' perception toward robots within the COVID-19 pandemic. Consequently, their awareness and education have to be increased to understand the opportunities, functions, and features of these tools. Furthermore, as reported in the literature, a familiarization stage in the first instance is recommendable to increase healthcare personnel's trust and motivation. This stage will achieve the successful adaptation of the technology during the COVID-19 pandemic. Despite this level of awareness, participants explain a positive attitude toward robots in managing and mitigating the effects of the COVID-19 pandemic [6]

IV. APPLICATIONS OF ROBOTS IN HEALTHCARE

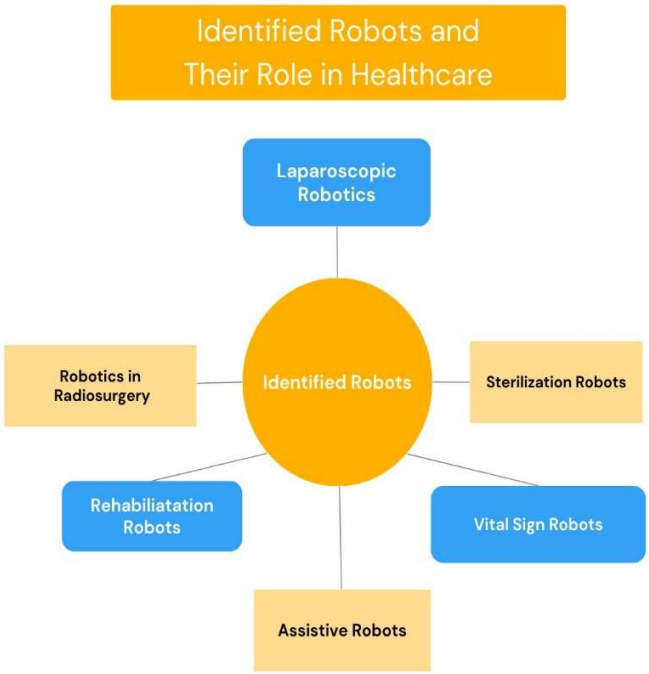

Fig. 2. Identified Robots

4.1 Laparoscopic Robotics

Laparoscopic robots are the most commercially successful medical robotics equipment of their type. The quantity of development during the last decade has been measured in three categories: clinical, commercial, and academic. There has been an increase in research into laparoscopic robots, including clinical trials to evaluate the effectiveness of various models. This field encompasses radiation prostatectomy, radical cystectomy for bladder cancer, thymectomies, and rectal cancer resection. In the past, laparoscopic surgery was performed manually. Due to many limitations of that habit, a research project funded by the US Army aimed to do the operation for injured soldiers

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In the past, laparoscopic surgery was performed manually. Due to the many limitations of that habit, a research project funded by the US Army aimed to do the operation for injured soldiers remotely and to minimize the limitation of manual operation, which led to this. The Da Vinci robot, which is the most common laparoscopic robot used for different laparoscopic surgeries, this robot had two operating systems .The logistics robot played a pivotal role during the COVID-19 pandemic in reducing infection among healthcare members, robots are not capable of catching diseases, and for that reason, their role of them gets more attention during the pandemic[7]

4.2 Sterilization Robots

Sterilization robots are automated devices made to efficiently clean and sanitize a various variety of surfaces and surroundings, especially in medical facilities. These sophisticated robots remove dangerous pathogens, such as bacteria, viruses, and fungus, by using ultraviolet (UV) light, hydrogen peroxide vapor, or other disinfection agents.

An example of the high rate of spreading viruses in the hospital is the result of , their results show that 53% of influenza virus particles are mostly found within a respirable aerosol fraction, which proves that viruses spread through the airborne route. COVID-19 has a high rate of spreading in different environments such as hospitals. The different presence rates of different viruses within the hospitals led to finding a way for an optimal sterilization process to reduce the risk of infection.[8-9]

4.3 Vital Sign Robot

During the COVID-19 epidemic, there was a decline in face-to-face communication since most daily duties were completed online or at a social distance from one another. Patients with a wide range of ailments were being admitted to hospitals, and there was a significant chance that they would contract the coronavirus. Medical robots play a crucial role in preventing infections and mitigating the danger of virus transmission among patients and healthcare personnel. Vital sign assessment is a crucial examination for all patients and guests in medical facilities; the pandemic created a demand for visitor scanning. The risk of nurse personnel contracting the coronavirus is high because this examination necessitates a nurse who has direct human contact to take vital signs.

A quadruped robot was developed during the pandemic to measure vital signs without direct contact with the patients. This robot moves autonomously and keeps a social distance from the patients. It simultaneously measures the blood oxygen saturation, respiratory rate, skin temperature and heart rate by applying advanced algorithms in Computer Vision (CV) and machine learning for more efficient tracking of the Region of Interest (ROI) using Infra-Red (IR) camera and monochrome camera. Implementing this way of measuring the vital signs will reduce the direct contact with the patients, efficiency will increase and the risk of infectious micro-organisms spreading will be minimized[10]

A Vital Sign Robot is a robot that monitors and measures a patient's vital signs, which commonly include characteristics like heart rate, blood pressure, respiration rate, temperature, and, in some cases, oxygen saturation levels (SpO2). These vital indicators reveal critical information about a person's physiological state and overall health.
Overall, Vital Sign Robots are beneficial in healthcare settings because they automate vital sign monitoring, allow for early detection of health disorders, and provide more efficient and accurate patient treatment. They are particularly beneficial in settings such as hospitals, clinics, nursing homes, and home healthcare, where continuous monitoring of patients' vital signs is critical for early intervention and improved clinical results.

4.4 Robotics in Radiosurgery

Taking a treatment using radiation seeks to damage the cancer cells in the body by destroying the Deoxyribonucleic Acid (DNA) of those cells, radiosurgery is the surgery where ionizing radiation is focused on a selective tissue to destroys the cancer cell in that organ, it is commonly used for brain metastasis patient and primary tumours including vestibular schwannomas or pituitary tumours.[30] An example of a robotic radiosurgery system that runs in the third decade of it is conception is the Cyber Knife robotic radiosurgery system, which delivers a non-invasive treatment for a different cancerous condition where radiotherapy is suggested. It is used to treat the prostate, lung, brain, spine, head and neck, liver, pancreas and kidney, Cyber Knife can perform noninvasive radiosurgery in places where the tumour cannot be eliminated surgically.[11]-[12].

Radiosurgery is a medical procedure that uses highly focused beams of radiation to precisely target and treat tumors and other abnormalities in the body. Robotics in radiosurgery is the application of robotic technology to increase the precision, efficiency, and safety of radiation therapy administration. Here is an overview of how robots are utilized in radiosurgery.
Overall, robotics in radiosurgery represents a tremendous development in the field of radiation oncology, offering patients precise, non-invasive treatment alternatives with better outcomes and fewer side effects. The development of the system and it is software during the three past decades leading to optimizing the treatment planning for the patients, targeting and tracking accuracy were enhanced, the dose calculation accuracy was improved, Minimize the dose of the treated and irradiated volumes and applicability of the system to lesions throughout the body were expanded.

4.5 Rehabilitation Robots

Rehabilitation robots are a sort of robot that is specifically created to assist individuals with physical limitations during the rehabilitation process. Debilitating motor impairment disorders include stroke, multiple sclerosis, trauma to the head and spinal cord, and spina bifida [13].

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Rehabilitation robots assist patients in recovering movement and functionality following an injury or illness. They provide individualized therapy sessions that are tailored to each individual's distinct needs. These robots can do real-world chores to help with recovery. They give users feedback to help them improve their movement and coordination. Patients can use these robots to rehabilitate their upper and lower limbs. They significantly increase the efficacy of rehabilitation therapy. They also enable remote monitoring and modification of therapeutic sessions..

4.6 **Assistive Robots**

Assistive robots are designed to make daily tasks easier for those with limits or disabilities. These robots can take many different shapes; they can be simple devices or complex systems with artificial intelligence and state-of-the-art sensors.
Their primary goal is to help people with disabilities gain more independence and quality of life by assisting them with mobility, communication, personal care, and home activities. Assistive robots can help people with limited mobility walk, change surfaces, and navigate their surroundings. Communication assistive robots employ voice recognition and synthesis technology to help persons with speech impairments communicate more efficiently. They can convert spoken words or gestures into text or a synthetic voice, enabling individuals to communicate.

V. TYPES OF FRAMEWORK

The use of technological processes and procedures can be considered inevitable for health organizations, with the creation and development of certain technological practices, everything pointed to the use of different areas in all possible fields. With the emergence and development of new diseases, technologies began to be seen as an opportunity to better
understand and evaluate the particularities of each case [14].

The computer came to be considered a fundamental technological tool for health agencies; its use provides greater security to professionals in relation to the development data of their activity. As well as providing certain procedures that can be applied to help in the constitution of accurate reports of the activities carried out and the procedures applied, as a way of observing if they are in accordance with the observed issues [14-15].

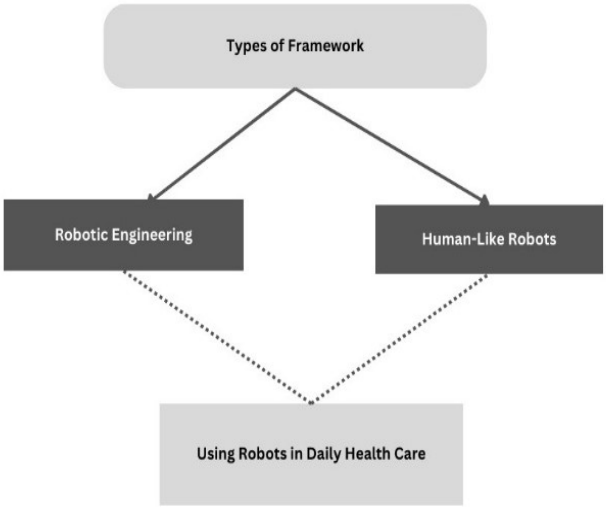

Fig. 3. Types of Framework

5.1 Robitics Engineering

The idea and purpose of care robots are shown to have the potential to stimulate innovative policies at the discursive level and the care sector at the organizational level. The need for care robots stems from the third strand, which examines the epistemic conditions surrounding robot development. A later discursive and overt context for service robots is provided by certain sociotechnical conditions that impact robot developers when developing them for use outside of labs. [14-16].

A thorough framework for comprehending and utilizing the advantages of robots in healthcare is provided by robotics in engineering. Thus, one can create a future where robotics improves patient care, outcomes, and the delivery of healthcare services by embracing interdisciplinary collaboration, utilizing theoretical frameworks, and confronting obstacles head-on.

5.2 Human-like Robots

Humanoids presented a particularly interesting illustration of the tension between human hopes and expectations of robots and the apprehension of their use in healthcare settings. They also represent an important socio-technical example, as the human and technical dimensions blur together in challenging and highly visible ways [14-17].
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The main goal of some robotics researchers is to build robots that resemble people, both in body and behavior. Until now, however, the most used robots in robotics research have been manipulator robots, mobile robots and robots with legs. On the other hand, In recent years, Japanese industries has made so many strides in building humanoid robots that we have to ask ourselves what role these robots might play in the future of robotics society [18].

Currently, research with humanoid robots is more focused on bipedal locomotion than on cognition, when it is known that both aspects were linked during human evolution, as it was bipedal walking that allowed hominids to release their hands in order to create and manipulate tools and thus develop cognition [19].

Human-like robots are a game-changer for the healthcare industry, opening up new avenues for patient care and providing creative answers to persistent problems. Thus, One can fully utilize the potential of humanoid robots to improve patient outcomes, healthcare delivery, and the development of a more compassionate and inclusive healthcare ecosystem by integrating them responsibly, taking ethical issues into account, and working together continuously.

5.3 Using Robots in Daily Health Care

Service robot programs seek to improve human-robot interactions in real-world settings. This type is frequently distinguished by the presence of non-technical experts in gerontology, nursing science, and medicine. This sort of support robotics is defined as ground-breaking research that prepares and tests the use of robots in care, with the goal of generalizing beyond the unique application context for which they are designed.
During the development phase, engineers might get feedback from secondary and tertiary users, such as nursing staff and family members. This is because the relevant application and testing sites for such efforts are in highly institutionalized settings like care facilities or wards.

Robot deployments in healthcare environments are likely to increase due to increasing technological capabilities, their reduced costs, and increasing pressure to reduce costs.However, robots are potentially highly disruptive innovations and, therefore, it is important to understand the socio-technical challenges that may be encountered as robots are deployed to find mitigation strategies [14-22].

Sociotechnical approaches to studying technology implementation see social and technical factors shaping each other over time. It is assumed that technologies are shaped by their social environments (e.g., through projects being modified), but also that social environments are shaped by technological resources (e.g., when users' work practices change as a result of change). introduction of technology) [14].

Silva and Caetano (2020) stated that the field of robotics in healthcare environments was still in its infancy and the shift in the role to EHRs currently has a strategic priority over investments in robotics. Specifically, the most innovative developments around humanoids were still a long way off in

terms of routine deployment in healthcare and care settings, while service robots were seen as having the greatest near-term promise. However, it was also recognized that there was significant potential and the pace of developments, as well as the increasing convergence of applications, meant that robotics was likely to become a routine aspect of healthcare delivery at some point [23].

The widespread implementation of robotics in healthcare has great potential to improve patient care, boost productivity, and advance healthcare delivery. By utilizing the revolutionary potential of robots, one can can establish a healthcare system that is more accessible, efficient, and compassionate for everyone, all via careful planning, smart execution, and continuous collaboration.

VI. BENEFITS AND RISKS INVOLVED

Robotics is changing healthcare, benefiting both patients and medical professionals. Robots improve surgical precision and control, resulting in less invasive surgeries with smaller incisions, lower blood loss, and faster patient recovery. This reduces discomfort, scarring, and the risk of infection. Robotic helpers give surgeons extraordinary dexterity and wider views, allowing them to conduct complex surgeries more efficiently and consistently. Beyond surgery, robots are revolutionizing other aspects of healthcare. They can automate time-consuming chores such as drug distribution and cleaning, freeing up nurses and doctors to focus on direct patient care. Robots in rehabilitation can provide patients with individualized assistance and data-driven feedback to help them regain mobility and functionality. Robots provide companionship, medication reminders, and vital sign monitoring to the elderly and those with chronic diseases, enhancing quality of life and enabling remote care. Furthermore, the use of robotics fosters innovation and improvement in medical technology.

Overall, the implementation of robotics in healthcare represents a paradigm shift that enhances patient care, accessibility, efficiency, safety, and innovation. As technology advances, robots have the ability to adapt. While robots have immense potential in the healthcare industry, their use is not without risks One key concern is patient safety. Even modest errors during surgery or other treatments might have catastrophic repercussions. Furthermore, the great levels of precision that robots achieve may not necessarily be practical in real-world contexts. Unexpected anatomical changes or challenges can disrupt the robot's programming, necessitating quick human intervention.
Another concern is data privacy and cybersecurity. Robots that collect patient data present security risks and unlawful access. Sensitive medical data must be protected with strict security measures.
Furthermore, increasing reliance on automation may result in the dehumanization of care.
Another barrier is the high expense of purchasing and maintaining robots. Some healthcare facilities may be unable to

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purchase this equipment, resulting in an uneven allocation of resources. Finally, the human dimension is irreplaceable. Robots lack empathy, intuition, and the ability to adjust to unexpected situations. Skilled medical experts will still be required to supervise robot procedures, interpret data, and offer emotional support to patients. The future of healthcare robotics depends on striking a balance between maximizing technological benefits and prioritizing human oversight and compassion.

Safety risk has been viewed as one of the most significant risk concerns for robot use in LTC. Frontline staff participants repeatedly emphasized that the cognitive and physical disabilities of residents made safety risk a priority concern. Although the telepresence robot was designed for autonomous navigation to avoid collision, some participants voiced concerns that mobile robots could malfunction or move into the wrong places, such as bathrooms or areas that were out of bounds. One care worker participant was concerned the mobility issue of the robot would trigger behaviors among residents with dementia[24].

Furthermore, there are ethical considerations with the use of robots in healthcare. As these machines do increasingly complex tasks, concerns regarding accountability, responsibility, and delegation of decision-making authority arise. When robots are utilized in patient care, it is difficult to determine accountability in the event of bad outcomes or errors, which can lead to legal and ethical quandaries.

Furthermore, the application of robotic technologies in healthcare may worsen existing socioeconomic imbalances.

The high costs of acquiring, maintaining, and updating robotic systems may worsen the disparity in access to contemporary medical treatment between affluent and poor populations, prolonging health disparities.

Robots in healthcare have substantial potential benefits, including higher surgical precision, faster and more accurate diagnosis, and improved patient care by automating repetitive chores. They can work for long periods of time without fatigue, reducing errors and improving overall efficiency. Furthermore, robots can provide remote patient monitoring and care, improving healthcare access, especially in impoverished areas. However, its adoption raises worries about job displacement among healthcare workers, as well as ethical quandaries around decision-making autonomy. Furthermore, there are hazards linked with technical failures or hacking, which may jeopardize patient safety and confidentiality. In order to successfully integrate robotics into healthcare, it is imperative to achieve equilibrium between maximizing benefits and reducing potential risks.

VII. CONCLUSION

The integration of robots into healthcare presents an intriguing and problematic prospect. This study looked into the various benefits that robots offer, such as increased surgical precision and efficiency, automation of tedious tasks, and patient companionship. Robots have the potential to alter healthcare delivery, reducing the burden on overworked staff while improving patient outcomes. However, the discussion would be incomplete without acknowledging the inherent risks associated with this technology. Concerns about patient safety, data security, and the possibility of dehumanizing treatment must all be carefully evaluated. The potential for failure or malfunction in robotic systems is a major cause of concern. Despite significant technological developments, robots are still prone to technical faults, software issues, and mechanical failures. Such issues can result in an incorrect diagnosis, insufficient treatment, or inadvertent patient damage. Despite extensive testing, the complexity of robotic systems can make it difficult to discover and address these issues. Furthermore, the absence of defined norms and procedures for the employment of robots in healthcare is a significant obstacle. Unlike traditional medical equipment, which is subjected to stringent regulatory examination, robotic technology regularly outperforms regulatory norms. This regulatory gap raises questions about the safety and efficacy of robotic devices, putting healthcare providers and patients at risk of harm.

The human touch is still crucial in healthcare. Robots lack empathy, intuition, and the ability to adjust to unexpected situations. Skilled medical professionals will continue to set the framework for treatment by monitoring robot operations, interpreting data, and offering emotional support that robots cannot. The future of healthcare robotics is to foster collaborative interactions between humans and robots. By combining the benefits of technology with human oversight and compassion, we may usher in a new era of healthcare delivery that is both efficient and truly humane.

The need of the hour is to educate the upcoming generation on the field of robotics technology and develop new technologies to make robotics efficient and viable in healthcare. Good research

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and development also needs to be focused on as shown in this research paper, along with public information campaigns to educate the general public about this new and emerging field of technology[3].

Finally, the employment of robots in healthcare has enormous potential while also presenting considerable challenges. By embracing both sides of the coin and encouraging a collaborative approach between humans and machines, we may realize the full promise of robotic healthcare, paving the way for a future in which technology improves, rather than diminishes, the human experience in the medical context.

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