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A review on scope and use of Robots in healthcare sector in Kerala and related ethical issues

Ancy Varghese[1]*, Ojus Thomas Lee[2]

[1] Asisstant Professor, Department of Electronics, SAINTGITS College of Engineering, Kottayam, India

[2] Associate Professor, Department of Computer Science, College of Engineering, Kidangoor, Kottayam, India

E-mail: ancy.varghese@saintgits.org

Abstract

In today's rapidly evolving world, robots have become integral to various industries, including healthcare. Their precision, efficiency, and ability to perform repetitive tasks have transformed patient care and clinical procedures. While developed countries have embraced robotic technologies, India, particularly Kerala, is still in the early stages of integrating robots into healthcare. Surgical assistance and patient rehabilitation are key use cases. However, this adoption raises ethical, privacy, and regulatory concerns. As technology advances, robots will play an increasingly vital role in healthcare delivery, necessitating thoughtful consideration of ethical implications. This work highlights the promise and challenges of healthcare robotics, emphasizing the need for responsible implementation and ethical safeguards.

Keywords: *Health care Robots, Surgical Robots, Hospital Robots, Ethical issues in Robotics, Delivery Robots*

INTRODUCTION

In today's world, robots play a variety of roles in manufacturing, healthcare, agriculture, entertainment, and many other industries and sectors. Their ability to carry out repetitive tasks with accuracy, efficiency, and repeatability has revolutionized many industries, improving productivity, quality, and safety. As technology advances, the utilization of robots in today's world is expected to increase, changing industries, changing work processes, and changing the way we interact, live, and work with technology.

Robots, AI and automation are playing an important role in the healthcare industry, especially in developed countries, where robots help doctors and medical staff to perform complex tasks with precision and reduce the burden of medical personnel, thereby improving the efficiency of healthcare services. Robotics in healthcare has use cases such as surgical assistance, patient rehabilitation and more. Healthcare industry has been revolutionized by robotics by providing better patient care, simplifying clinical procedures and creating safer environments for patients and healthcare professionals. The footing of robotics in medicine outside of India is rapidly advancing, with robotic

technologies playing a pivotal role in reshaping various aspects of healthcare across the globe. However, the use of robots in Indian hospitals, particularly in Kerala, is still in the early stages, especially in the area of surgical assistance. While there are many benefits to using robots in healthcare, such as increased efficiency and better patient care, their integration raises ethical, privacy and regulatory issues. As technology advances, the robots will play an important role in medicine and healthcare delivery. In this review, we discuss the types of robots that are in the healthcare industry and the use of such robots in hospitals in India, as well as the ethical considerations of using robots in hospitals [1].

In this survey paper, we're going to look at some of the different types of robots that are used to help healthcare workers, like nurses, caregivers and therapists. This article guides you through the following topics; types of robots used in healthcare, commercially available robots used in healthcare for delivery and disinfection, vulnerabilities while implementing healthcare robots, ethical concerns, extend to which hospitals in Kerala are using robots for healthcare.

These queries let us assess the state of healthcare robot technological readiness as well as the possible areas for future study and development that will be required to include robots into environments that prioritize people.

SCOPE OF ROBOTS IN HEALTHCARE

The integration of robotics within hospital settings represents a transformative leap in modern healthcare, offering a broad spectrum of applications that revolutionize patient care, operational efficiency, and medical procedures. Robotics in hospitals encompass a diverse array of technologies, ranging from surgical robots that assist in minimally invasive procedures to telepresence robots facilitating remote consultations and patient monitoring [2]. These innovative systems hold the promise of enhancing surgical precision, reducing recovery times, and minimizing the risk of human error. Beyond the operating room, robots are also deployed to handle tasks such as medication delivery, disinfection, and patient assistance, thereby alleviating strain on healthcare staff and improving overall workflow efficiency. As hospitals embrace these advancements, the scope of robotics continues to expand, ushering in an era of safer, more accessible, and patient-centered care.

Overall, the integration of robotics in the healthcare industry holds tremendous potential for improving patient care, enhancing efficiency, reducing costs, and addressing the challenges posed by an aging population and the increasing demand for healthcare services [4]. Hospitals can overcome human errors, staff shortages, infection control, physical strain on healthcare workers, language and cultural barriers. Robots have the potential to improve hospital healthcare delivery in terms of quality, safety, and efficiency by overcoming these obstacles, which will eventually improve patient outcomes and experiences. We may anticipate more technological advancements and robotics-related applications in the healthcare industry, which may ultimately change how medical care is provided and experienced.

TYPES OF ROBOTS IN HEALTHCARE

Robots are used in healthcare industry in diverse use cases. A snapshot of the robots used for patient care in hospital environments is presented here.

Surgical Robots: Surgical robots, namely the da Vinci Surgical System, have revolutionized minimally invasive surgery. These robots assist surgeons in performing precise procedures with greater accuracy, dexterity, and control, leading to reduced recovery times, less trauma for patients, and improved surgical outcomes. The most predominant one in this category is the da Vinci surgical system [12]. Zeus and da Vinci is designed to mimic the hand movements of the surgeon [13].

Telepresence Robots: Telepresence robots [11] enable remote patient monitoring and consultation, allowing healthcare providers to interact with patients and other medical staff from a distance. These robots are equipped with cameras, microphones, and screens, providing a virtual presence for healthcare professionals to conduct examinations, check-ups, and consultations without physically being present. Ohmni Robot by OhmniLabs, Double 3 by Double Robotics and Ava by Ava Robotics are a the widely used telepresence robots.

Rehabilitation Robots: Rehabilitation robots assist patients in recovering from injuries or surgeries by providing personalized therapy sessions. These robots can help patients regain mobility, strength, and function through repetitive exercises and movements tailored to their specific needs. Exoskeleton robots [4], end-effector based rehabilitation robots [5], upper limb and lower limb rehabilitation robots [6,7] helps the patient to rehabilitate various motor skills.

Delivery Robots: In hospitals, delivery robots are used to transport supplies, medications, and other items between different departments, reducing the need for human personnel to perform these tasks manually. These robots can navigate through hospital corridors autonomously, improving efficiency and reducing the risk of errors. Moxi [3], by Diligent Robotics helps in running patient supplies, delivering lab samples, PPE and medications. TUG by Aethon [10] is also a delivery robot, but without manipulator.
Assistive Robots: Assistive robots aid healthcare professionals in lifting and transferring patients, reducing the risk of injuries associated with manual patient handling. These robots can also assist patients with activities of daily living, such as feeding, bathing, and dressing, particularly in long-term care facilities and nursing homes. Examples of assistive robots include FRIEND, an intelligent wheelchair mounted manipulator [8] and seven DOF Jaco 2 arm [9], mainly intended to feed the patient and can be controlled by gestures and eye trackers.

Diagnostic Robots: Diagnostic robots equipped with artificial intelligence algorithms can analyze medical imaging scans, such as X-rays, MRIs, and CT scans, to assist radiologists and other healthcare professionals in detecting abnormalities and making accurate diagnoses. Vivo laparoscopic robots and endoscopic robots are used for minimally invasive diagnosis [13].

DELIVERY ROBOTS USED IN HOSPITALS

We introduce a set of delivery robots that are currently used in hospitals in this section.
Cloud Minds Robotics, a global AI technology company, manufactures healthcare robots equipped with advanced machine learning capabilities, aiding hospitals in tasks such as patient monitoring and data analysis. Their robots utilize cloud-based infrastructure for seamless integration with hospital systems, enhancing operational efficiency and patient care. Cloud Ginger Lite D series shown in Fig. 1, incorporates auto navigation and obstacle avoidance using SLAM and VSLAM technology based on multiple sensors and 3D environment perception, this helps it to run in complex scenarios. These humanoid robots can be used for multi-functions such as delivery, sanitation, reception, guidance etc. Ginger Lite D300, a multi-functional medicine-delivery robot tailored for hospitals, with recent deployment in medical facilities across Beijing, Shenyang, and Jinan. Equipped with autonomous navigation, elevator riding, and obstacle avoidance capabilities, these robots streamline the delivery of medications between different hospital areas, ensuring efficient and safe operations across floors and regions. With an abundance of sensors at its disposal, the robot can sense its surroundings and identify any dead ends. To protect the materials and medications, it offers a sealed box and employs password verification. In a formal statement, the Chinese Ministry of Science and Technology approved of Cloud Minds' development of the "New Generation of Cloud Robot National Artificial Intelligence Open Innovation Platform"[14]. Large volume difficulties are resolved by the robot.

Fig. 1: *Cloud Ginger Lite [14]*

Fig. 2: *Diligent Moxi [3]*

Diligent, a robotics solutions provider [3], specializes in manufacturing robots optimized for hospital logistics, such as inventory management and surgical assistance. Their robots are equipped with intuitive interfaces and smart algorithms, enabling seamless integration into existing hospital workflows to streamline processes and improve overall efficiency. Many hospitals around United States of America have successfully adopted the Moxi robot from Diligent Robotics, which is depicted in Fig. 2. In NorthShore Edward-Elmhurst Health, Moxi assists with tasks such as delivering supplies, medication, and equipment within their healthcare facilities. In University of Texas Affiliated Network of Health Systems and Northwestern Medicine, Moxi demonstrates its adaptability and positive impact on hospital workflows. Using a Freight mobile base from Fetch Robotics, Moxi is able to manipulate objects with the help of an Adaptive Gripper from Robotiq, an Intel RealSense, a Kinova Jaco arm, and several RGB-D cameras [15]. To extend the reach of its Moxi robot over the majority of its 22 health system clients, Diligent Robotics has secured funds totaling $25 million. The company intends to install over 100 robots at over 30 hospitals and triple its market share.

Aethon, a pioneer in autonomous mobile robotics, manufactures TUG robots specifically tailored for hospital applications, including meal delivery and waste management is shown in Fig. 3. Biometric security enhanced door carts helps to ensure safe delivery of sensitive medications and laboratory specimens. Their robots feature robust construction and advanced navigation technology, ensuring reliable performance in demanding healthcare environments while enhancing staff productivity and patient satisfaction. It is designed as an autonomous navigation system using camera and laser technology. TUG robots are manufactured and supported in United States and serves more than hundred hospitals across the United States.

Fig. 3: *TUG [16]*

Fig. 4: *Xenex [17]*

Xenex, a leader in UV disinfection technology [17], produces robots that utilize ultraviolet light to effectively sanitize non-porous equipment, un-occupied hospital rooms and operating rooms where critical medical devices are not present. Using a xenon lamp, the LightStrike Xenex robot, shown in

Fig. 4, emits high-intensity pulsed broad spectrum UV light, reducing the number of pathogens present on surfaces and interrupting the transmission of pathogens from surfaces to patients or healthcare workers. Manufactured with high-quality materials and precision engineering, Xenex robots provide an additional layer of protection against harmful pathogens, contributing to a safer and cleaner healthcare environment for both patients and staff.

A few more robotic solutions such as UVD Robots, Skytron etc. also offers solutions designed to combat healthcare-associated infections using UV-C light and sterilization systems.

ROBOTS IN HEALTH CARE SECTOR IN KERALA

The scope of robots in hospitals in Kerala is expanding, the main application is robotic surgery. Robotic systems are being used across various surgical specialties, including gynecology, oncology, urology, surgical gastroenterology, thoracic surgery, general surgery, and head and neck surgery. These systems offer superior visualization, precision, and efficiency, leading to smaller incisions, less pain, quicker recovery, and reduced risk of infection. Hospitals in Kerala which have implemented robotic surgery, including:

Aster Medcity, Kochi [18]: Aster Medcity is one of the leading hospitals in Kerala offering robotic surgery services. They utilize the da Vinci Surgical System, a state-of-the-art robotic platform, for various procedures including urological, gynecological, and gastrointestinal surgeries. Robotic surgery at Aster Medcity allows for enhanced precision, shorter hospital stays, and quicker recovery times for patients.

Amrita Institute of Medical Sciences (AIMS), Kochi [19]: AIMS is another prominent hospital in Kerala known for its advanced healthcare services, including robotic surgery. They employ robotic-assisted techniques for procedures such as prostatectomy, hysterectomy, and colorectal surgery. Robotic surgery at AIMS offers patients the benefits of reduced blood loss, smaller incisions, and faster return to normal activities.

KIMS Hospital, Thiruvananthapuram [20]: KIMS Hospital in Thiruvananthapuram is equipped with robotic surgical systems for performing complex procedures across various specialties. The hospital utilizes robotics for surgeries such as cardiac bypass, thoracic surgery, and urological interventions. Robotic surgery at KIMS Hospital ensures greater surgical precision, improved outcomes, and enhanced patient satisfaction.

Rajagiri Hospital, Aluva [21]: Rajagiri Hospital offers robotic surgery services using the da Vinci Surgical System. This advanced technology enables surgeons to perform minimally invasive procedures with enhanced precision and control. Rajagiri Hospital utilizes robotic-assisted techniques for a range of surgeries including urological, gynecological, and gastrointestinal procedures. Patients undergoing robotic surgery at Rajagiri Hospital experience shorter hospital stays, reduced postoperative pain, and faster recovery times compared to traditional surgery methods.

Aster MIMS, Kozhikode [22]: Aster MIMS, Kozhikode is at the forefront of robotic surgery in Kerala. Equipped with the latest robotic surgical systems, including the da Vinci Surgical System, Aster MIMS offers minimally invasive robotic-assisted procedures across various specialties such as urology, gynecology, and oncology. Robotic surgery at Aster MIMS ensures superior surgical precision, minimal scarring, and quicker recovery for patients. The hospital's commitment to innovation and technology ensures that patients receive world-class surgical care with the benefits of advanced robotics.

These hospitals showcase the adoption of cutting-edge robotic technologies in Kerala's healthcare landscape, providing patients with access to state-of-the-art surgical treatments and enhancing overall healthcare outcomes.

POTENTIAL VULNERABILITIES

The integration of robots in hospitals, while beneficial, also introduces potential vulnerabilities [23,24,25]. Exploited robots can disrupt or impede the timely delivery of medications, lab samples, and other critical supplies. They can interfere with hospital elevators, door locking systems, and even crash into people or objects. Unauthorized access to patient data and medical records compromises privacy

and confidentiality. A set of reported vulnerabilities are discussed here. Remote Hacking allow remote attackers to compromise the robots. Researchers have discovered serious vulnerabilities in Aethon's TUG autonomous mobile robots used in hundreds of hospitals worldwide. Lack of Authorization and Identity Checks allows an unauthenticated attacker can add new admin users, access credentials, and hijack the robot. This lack of robust security measures poses a significant risk to patient care and hospital operations. Network Security and Malware Deployment: Hijacked robots can be used for surveillance through integrated cameras. Attackers may deploy malware on compromised robots, potentially infiltrating the hospital network for further malicious activities. Robust security measures, regular vulnerability assessments, and timely patching are essential to mitigate these risks. Hospitals must collaborate with vendors, strengthen network defenses, and prioritize patient safety while leveraging the benefits of robotic technology[26].

ETHICAL CONSIDERATIONS WHILE ADOPTING ROBOTS FOR HEALTH CARE

As hospitals increasingly integrate robotic technologies into their healthcare systems, it is crucial to address the ethical implications associated with their use. The Indian Council of Medical Research (ICMR) recognizes the importance of ensuring that robotic applications in hospitals adhere to ethical principles to safeguard patient rights, privacy, and overall well-being. Therefore, the ICMR has formulated guidelines outlining ethical considerations in the development, implementation, and utilization of robots in hospital settings.

The Indian Council of Medical Research (ICMR) emphasizes patient safety in using robots in hospitals, requiring thorough testing and training for healthcare professionals. Privacy is crucial, with strong encryption and access controls needed to protect sensitive data. Patient autonomy and informed consent are vital, with transparency about robot use necessary for informed decision-making. The equitable distribution of resources is emphasized to avoid exacerbating healthcare disparities. Professional responsibility includes ethical use of robotic technologies, with monitoring mechanisms needed for compliance. The ICMR's ethical framework guides the responsible deployment of robots in healthcare, prioritizing patient welfare while advancing healthcare delivery. Collaboration among policymakers, healthcare institutions, and technology developers is essential to ensure ethical standards are upheld in robotic technology use in hospitals.

CONCLUSIONS

Robots are used in many different businesses and sectors nowadays, including industry, healthcare, agriculture, and entertainment. Many sectors have seen a revolution as a result of their capacity to perform repeated activities with accuracy, efficiency, and repeatability, which has increased production, quality, and safety. Robotics will likely be used more and more in today's society as technology develops, transforming work processes, industries, and how humans interact, live, and use technology. Automation, artificial intelligence, and robotics are all becoming increasingly prevalent in the healthcare sector, particularly in developed nations. These technologies relieve medical staff members of labor-intensive duties and help physicians perform complex procedures with greater accuracy. As a result, healthcare services are provided more efficiently.

REFERENCES

1. Kyrarini, M.; Lygerakis, F.; Rajavenkatanarayanan, A.; Sevastopoulos, C.; Nambiappan, H.R.; Chaitanya, K.K.; Babu, A.R.; Mathew, J.; Makedon, F. A Survey of Robots in Healthcare. Technologies 2021, 9, 8. https://doi.org/10.3390/technologies9010008
2. González-González, C.S.; Violant-Holz, V.; Gil-Iranzo, R.M. Social Robots in Hospitals: A Systematic Review. Appl. Sci. 2021, 11, 5976. https://doi.org/10.3390/app11135976
3. Care is a team effort. Available online: https://diligentrobots.com/moxi (accessed on 02 April 2024).
4. Rehmat, N.; Zuo, J.; Meng, W.; Liu, Q.; Xie, S.Q.; Liang, H. Upper limb rehabilitation using robotic exoskeleton systems: A systematic review. Int. J. Intell. Robot. Appl. 2018, 2, 283–295.

5. Liu, Y.; Li, C.; Ji, L.; Bi, S.; Zhang, X.; Huo, J.; Ji, R. Development and implementation of an end-effector upper limb rehabilitation robot for hemiplegic patients with line and circle tracking training. J. Healthc. Eng. 2017, 2017, 4931217.
6. Maciejasz, P.; Eschweiler, J.; Gerlach-Hahn, K.; Jansen-Toy, A.; Leonhardt, S. A survey on robotic devices for upper limb rehabilitation. J. Neuroeng. Rehabil. 2014, 11, 3.
7. Hobbs, B.; Artemiadis, P. A Review of Robot-Assisted Lower-Limb Stroke Therapy: Unexplored Paths and Future Directions in Gait Rehabilitation. Front. Neurorobot. 2020, 14, 1–16.
8. Graser, A.; Heyer, T.; Fotoohi, L.; Lange, U.; Kampe, H.; Enjarini, B.; Heyer, S.; Fragkopoulos, C.; Ristic-Durrant, D. A supportive friend at work: Robotic workplace assistance for the disabled. IEEE Robot. Autom. Mag. 2013, 20, 148–159.
9. Kyrarini, M.; Zheng, Q.; Haseeb, M.A.; Gräser, A. Robot Learning of Assistive Manipulation Tasks by Demonstration via Head Gesture-based Interface. In Proceedings of the 2019 IEEE 16th International Conference on Rehabilitation Robotics (ICORR), Toronto, ON, Canada, 24–28 June 2019; pp. 1139–1146.
10. TUG Autonomous Mobile Robots for Healthcare and Hospitality. Available online: https://aethon.com/mobile-robots-for-healthcare/ (accessed on 2nd April 2024).
11. I. -B. Păvăloiu, A. Vasilățeanu, R. Popa, D. Scurtu, A. Hang and N. Goga, "Healthcare Robotic Telepresence," 2021 13th International Conference on Electronics, Computers and Artificial Intelligence (ECAI), Pitesti, Romania, 2021, pp. 1-6, doi: 10.1109/ECAI52376.2021.9515025.
12. Morgan, A.A., Abdi, J., Syed, M.A.Q. et al. Robots in Healthcare: a Scoping Review. Curr Robot Rep 3, 271–280 (2022). https://doi.org/10.1007/s43154-022-00095-4
13. M. Nazmul Huda, Hongnian Yu, Shuang Cang, Robots for minimally invasive diagnosis and intervention, Robotics and Computer-Integrated Manufacturing, Volume 41,2016, Pages 127-144, ISSN 0736-5845, https://doi.org/10.1016/j.rcim.2016.03.003.
14. Cloud AI family. Available online: https:// https://www.cloudminds.com/en (accessed on 02 April 2024).
15. Moxi Prototype from Diligent Robotics Starts Helping Out in Hospitals by Evan Ackerman 18 Sept 2018. Available online: https://spectrum.ieee.org/moxi-prototype-from-diligent-robotics-starts-helping-out-in-hospitals (accessed on 05 April 2024).
16. Change Healthcare. Available online: https://aethon.com/ (accessed on 05 April 2024).
17. Xenex Germ-zapping solutions. Available online: https://xenex.com/light-strike-plus/ (accessed on 05 April 2024).
18. Aster hospitals. Available online: https://www.asterhospitals.in/hospitals/astermedcitykochi/specialities/urology/services/robotic-surgery (accessed on 05 April 2024).
19. Amritha hospitals. https://amritahospitals.org/kochi/department/centres-excellences /advanced- centre-robotic-surgery (accessed on 07 April 2024).
20. KIMS hospital. Available online: https://www.kimshealth.org/trivandrum/blog/robot-assisted-surgeries/ (accessed on 07 April 2024).
21. Rajagiri hospital. Available online: https://www.rajagirihospital.com/Rajagiri-Robotic-Surgery-Center/ (accessed on 07 April 2024).

22. Aster MIMS Calicut. Available online: https://www.asterhospitals.in/hospitals/aster-mims-calicut/specialities/obstetrics-gynaecology/services/minimal-access-robotic-surgery (accessed on 07 April 2024).
23. Health IT Security. Available online: https://www.healthitsecurity.com/news/jekyllbot5-vulnerabilities-impact-mobile-robot-used-in-healthcare (accessed on 07 April 2024).
24. The rise of Robotics in hospitals. Available online: https://business.libertymutual.com /insights/the-rise-of-robotics-in-hospitals-risks-and-rewards/ (accessed on 07 April 2024).
25. ZDNET. Available online: https://www.zdnet.com/article/critical-vulnerabilities-uncovered-in-medical-robots/ (accessed on 07 April 2024).
26. ICMR: Ethical guidelines. Available online: https://main.icmr.nic.in/content/ethical-guidelines-application-artificial-intelligence-biomedical-research-and-healthcare (accessed on 07 April 2024).