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Review

Revolutionizing Healthcare: Embracing Robotics and AI for Enhanced Patient Care

Ausaf Butool*, Asna Soha, Syeda Mariyam, Zainab Hussain, Dr. Anupama Koneru

Department of Pharmaceutical Chemistry, Sultan-ul-Uloom College of Pharmacy, Hyderabad, Telangana.

*Author for Correspondence: Ausaf Butool
Email: ausafbutool@gmail.com

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Abstract

This review enlightens the emerging role of artificial intelligence (AI) and robotics in the healthcare field. AI works with an amalgamation of extensive amounts of data using quick and complex algorithms. This allows the software to promptly adapt the pattern of the data characteristics. The use of AI along with robotics in the healthcare sector has shown an astounding rising trend in the past decade. The progressive advancements in big data analytics, cloud computing and artificial intelligence have led to increased research and development of intelligent robots in all walks of human life. Functions like conducting routine checkups, assisting surgery, streamlining hospital logistics are some of the tasks that may be carried out with great efficiency with the use of artificial intelligence in hospitals across the globe. Major advantages of application of robotic and AI in surgeries include better visualization, enhanced dexterity, greater precision, safer working conditions, operational tasks organized to perfection, etc. The future of this remunerative industry is anticipating a great revolution, aiming to create intelligent machines that work like humans. The perspective of AI and robotics in the future for healthcare sector comprises the care of geriatric population, discovery of new drugs, diagnosis of fatal diseases, elevating the clinical trials, predicting epidemic outbreaks, etc. However, the permanence of using robotics in health services may be questionable in terms of disbursement, conventional mindset of people. Robotics and AI in surgery is still in its infancy and its niche has not yet been chiseled. The present article accentuates AI's ability to revolutionize surgeries and its role in shaping the future of healthcare. This article gives a vast overview of AI in medicine, dealing with the terms and concepts as well as the present and future applications of AI. It aims to enhance knowledge and acquaintanceship of AI among primary healthcare physicians.

Keywords: Artificial intelligence (AI), software, data analytics, robots, healthcare, routine checkup.

INTRODUCTION

Artificial intelligence (AI) is the term used to describe the use of computers and technology to simulate intelligent behavior and critical thinking comparable to a human being [1]. Artificial intelligence in medicine is the use of machine learning models to assist process medical data and give medical professionals important discernment, improving health outcomes and patient experiences [2]. Machine learning allows AI applications to automatically ameliorate their algorithms through experiences gained by cognitive inputs or by the use of data [3]

The Need for AI and Robotics in Transforming healthcare sector

Over the decades, we have upgraded our knowledge and understanding about structure and function of the human body, including the organs, tissues, cells, cellular components etc. Meanwhile, we could further advance it up to the molecular and sub-molecular level, including DNA sequences, non-coding RNA, protein coding genes, etc. and their effects and behavior in the human body [4] . New tools based on AI have come into existence to predict the recurrence of diseases and progression or its response to treatment; and robotics, often categorized as a branch of AI, plays an crucial role in patient care [5] .

Benefits of AI in medicine

1. Informed Patient Care

Integrating medical AI into physician workflows can give healthcare providers valuable context while they're making care decisions. A trained machine learning algorithm can help reduce research time by giving clinicians valuable search results with evidence-based insights about procedures and treatments.

2. Error Reduction

3. Reducing Cost of Care

There are a lot of budding ways AI could cut down costs across the healthcare industry. Some of the most promising opportunities include reducing medication errors, customized virtual health assistance, prevention of fraud, and supporting more efficient administrative and clinical workflows.

4. Increasing Doctor-patient Engagement

In Many patients, questions arise outside of typical business hours. AI can help in providing around-the-clock support through chatbots that can answer basic and frequently asked questions and give patients resources when their provider's office isn't open. AI could also potentially be used to systematize questions and flag information for further review, which could help alert providers to health changes that need additional attention [6].

Classification of AI and Robotic Systems in Medicine

- Classification of the landscape of AI and robotic systems in health care can be done according to different dimensions, use, task, technology. Some of the various classifications includes

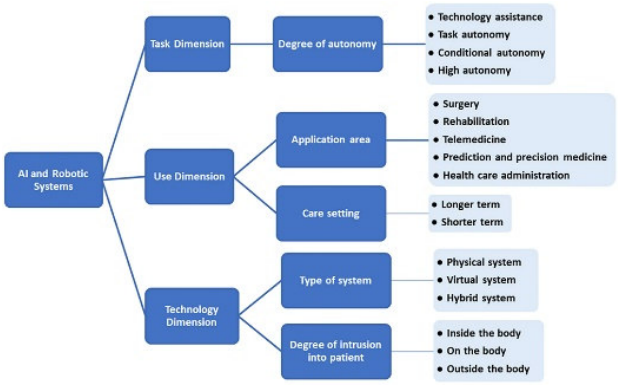


Figure 1. Categorization of systems based on AI and robotics in health care[3]

- Classification Based on Type of System

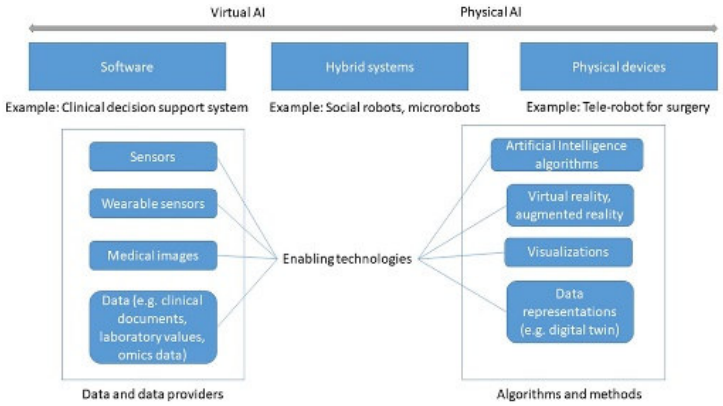


Figure 2. Types of AI-based systems and enabling technologies[3]

- Classification Based on Degree of Autonomy

	Technology assistance	Task autonomy	Conditional autonomy	High autonomy
Description	Caregiver is involved in task; system aids and enhances effectiveness and efficiency	Caregiver initiates task and controls execution by system	Caregiver defines and initiates a task; system executes task with supervision by human	Technology decides for action and executes it with caregiver execution
Example	System analyses patient data and highlights important facts	System analyses patient data and calculates a risk score	System analyses patient data and makes recommendations for examinations, physician always has to approve	System analyses patient data and makes / orders examinations without physician approval

Figure 3. Levels of autonomy of robotic and AI systems[3]

- Classification Based on Application Area-
  1. Robotics and AI for Surgery.
  2. Robotics and AI for Rehabilitation.
  3. Robotics and AI for Prediction and Precision Medicine.
  4. AI and Agents for Management and Support Tasks.
  5. Robotics and AI for Telemedicine.

- Classification Based on Care Setting-

Table 1. Classification by care setting[3]

Care setting		Description	Example
Longer term	Home care	Personal living environment	Remote monitoring of individuals for identifying early indications of heart failure decompensation, which allows for optimization of therapy to prevent hospitalizations (56)
	Assisted living facility	Residential facility with self-contained living units; site support 24 x 7 and capacity to arrange health care services	A smart kitchen for ambient assisted living (57)
	Nursing home	Facility providing residential accommodation with health care	Social robots to treat individuals with dementia in order to improve symptoms (58)
Shorter term	Inpatient hospital	Provides diagnostic, therapeutic and rehabilitation services by or under supervision of physicians	Virtual nurse for hospital discharge planning (59)
	Hospice	Facility that offers palliative and supportive care for terminally ill persons and their families	Conversational agent to collect patient reported outcome measures from individuals in palliative care (60)
	Inpatient psychiatric facility	Inpatient psychiatric services for the diagnosis and treatment of mental health disorders	AI to predict risk or severity of depression (61)

Selected care settings where robotic systems may be used [adapted from (62)].

Use of robotics and AI in healthcare

1. Assistance in Surgery

Use of AI and robotics in surgical field aims to amplify the capabilities of human beings and surmount human limitations in the field of surgery [7]. The introduction of the da Vinci Surgical System is one of the huge inventions in field of surgery [8]. Employment of high-definition computer vision enables surgeons to get detailed information about the inner condition of the patients which enhances their performance during the surgery [9].

2. Support to Healthcare Workers

The use of robotics and AI is not only limited to operating room but also it is useful in clinics and Outdoor Patient Departments in enhancing the patient care. The use of automation and robots is also observed in research laboratories where they are used to conduct several manual and repetitive tasks so that scientists can put their focus on more deliberate tasks and move faster towards new discoveries. These robots can also monitor the patients in a keener way compared to the human eye. Special robots called as "Social robots" can also be used for interaction with patients and also for encouraging them [10].

3. Protected Working Conditions

The role of ward boys, receptionists, nurses and other healthcare workers can be easily be substituted by robots. Some of the AI developed apps like the Arogya Setu app, by National Informatics Centre and Information Technology Ministry has proven to be a boon in the management of the COVID-19 pandemic [11].

4. Logistic Arrangements

Enabled medicine identifier software in robots helps in the distribution of medicines to patients in hospitals which makes it easier for the healthcare workers. Robots can also assist in cleaning and organizing patients' rooms autonomously, thereby reducing the risk of interpersonal contact in infectious disease wards [12].

5. Exclusive Patient Care

Socially assistive robots (SARs) are the result of the development of AI with physically assisted technologies. SARs are emotionally intelligent machines that lead to exclusive patient care, as these robots are capable of communicating with patients through a communicative range that makes them respond emotionally [13].

6. AI in Diagnosis

Reports suggest that about 80,000 people die every year due to wrong diagnoses of illnesses. Loads of excessive cases with partial details have led to severe mistakes in the past. As AI is resistant to these errors, it is capable of predicting and diagnosing diseases at a faster pace [14]. Many companies are using AI-supported tools for diagnosing and detecting different kinds of cancer [15].

7. Boost in Clinical Trials

Earlier the process of clinical trials was time consuming with poor outcomes and low success rates. Before year 2000, the success rate recorded for completing the clinical trials via all three stages, for the candidates was only 13.8% [16]. The execution of AI has cut down the cycle time and has also impacted the production cost and outcome in a positive direction [17].

8. Prediction of an Epidemic Outbreak

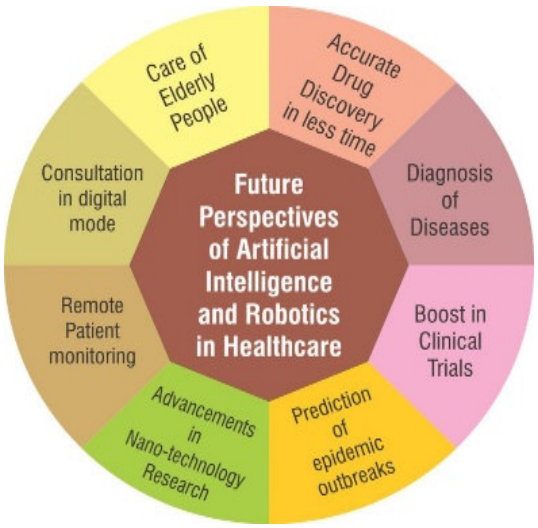
One of the most mind-blowing tasks of AI in healthcare is that it is proficient in forecasting the outbreak of an epidemic. Although it cannot control or mitigate the outbreak, it can warn us in advance for us to make preparations in time [18].

9. Organized Operational Tasks

Automated mobile robots (AMRs) regularize regular tasks, reduces the physical burden on health workers. These robots are also employed in doing diagnostic procedures like MRIs and X-rays and thus are of great advantage for healthcare workers, as it protects them from harmful radiations used in these procedures [19].

10. Future Perspective

The latest discoveries in machine learning have brought about a revolution in the health sector which focuses to create intelligent machines that work and respond like actual persons [8]. Although the application of AI and robotics in the healthcare sector is still in its infant stage, the future seems to be very bright in terms of acceptability and viability [20].



Adoption Challenges to AI and Robotics in Health Care:

While the range of opportunities and the accomplishments so far in robotics and AI are impressive as described above, several challenges hinder their implementation and acceptance in daily use. Challenges concerning trust, security, privacy, and ethics are widespread across all facets of healthcare, and many are deliberated upon in other sections of this publication. Thus, we will only briefly touch upon those obstacles that are distinct to AI and Robotics.

Resistance to Technology:

Healthcare providers might disregard or oppose new technologies for various reasons, such as real or perceived challenges to professional standing and independence [21], privacy worries [22], or the unsettled legal and

ethical issues surrounding accountability [23]. Concerns about job displacement by robots are as pressing in healthcare as in other fields. Presently, although surgical robots are becoming more autonomous, humans still carry out numerous tasks and hold a crucial role in guiding the robot's actions (e.g., in selecting process parameters or positioning the patient) [24].

Transparency and Explain ability:

Explain ability refers to "the ability of an AI-driven system for a person to reconstruct the reasoning behind a given prediction". Unlike rule-based systems, AI-driven predictions frequently lack explanations that humans can understand, potentially obscuring errors or biases (the "black box problem" of machine learning). The explain ability of AI models remains an active area of research. When physicians lack information about the rationale behind an AI-based decision, they cannot assess the reliability of the guidance, posing a risk to patient safety.

Responsibility, Accountability and Liability:

Responsibility for mistakes or harm caused by AI or robots falls on various parties depending on the level of autonomy of the system. According to the European Parliament's 2017 Resolution on AI, legal accountability for actions performed by an AI or robotic system is attributed to a human agent, who could be the owner, developer, manufacturer, or operator of the AI/robot.

Data Protection:

Machine learning relies on extensive datasets containing information about both patients and healthy individuals. This gives rise to concerns about data ownership, safeguarding against theft, adherence to regulations like HIPAA in the U.S. or GDPR for European citizens, and the appropriate level of anonymization of data. Regarding the latter issue, AI models may lead to unforeseen outcomes, and advancements in science could potentially enable patient re-identification in the future.

Data Quality and Integration:

Presently, the dependability and accuracy of data obtained from sensors and digital health devices are uncertain, highlighting a challenge for future research and development. Medical datasets inherently contain imperfections (such as noise, documentation errors, incompleteness, varying levels of detail in documentation, etc.), making it unfeasible to create machine learning models that are entirely free from errors. Moreover, the lack of efficient methods to swiftly and reliably integrate diverse data sources for analysis hinders the potential for rapid diagnosis by AI algorithms.

Safety and Security:

Introducing AI and robotics into healthcare delivery is likely to introduce new hazards and safety concerns. These risks can arise during normal operation due to design flaws, programming errors, configuration issues, or improper data handling.

These challenges are exacerbated when considering the potential for cyber-attacks:

Patient data might be exposed or stolen, potentially exploited by fraudsters for financial gain.

Security vulnerabilities in robots directly interacting with patients could lead to malfunctions which cause physical risks to patients or healthcare professionals. Such robots might cause harm directly or provide incorrect feedback to surgeons. In cases of unexpected robot behavior, users may struggle to discern whether the robot is functioning properly or has been compromised.

The EU Commission has recently developed a legal framework addressing the risks associated with AI, not limited to healthcare, aimed at enhancing AI safety and fostering trust. The framework categorizes risks into four levels: unacceptable, high, limited, and minimal. AI systems posing unacceptable risks will be prohibited, while high-risk applications must adhere to rigorous requirements before deployment (such as risk assessment, mitigation measures, and result traceability). Limited-risk applications like chatbots (used in telemedicine, for example) will require "labelling" to inform users that they are interacting with an AI-powered system.

Biases:

While P5 medicine aims to integrate various factors such as ethnicity, gender, socio-economic background, and education to tailor individualized care, current applications of AI often exhibit potential biases towards specific patient demographics. These biases may arise due to under-representation of certain groups in training datasets or variations in key features across different demographic categories. For instance, diseases like cardiovascular disease and Parkinson's disease progress differently in men and women, leading to varying distributions of relevant features. These factors contribute to unintended bias and "unnecessary discrimination" against subgroups. Conversely, conscientious implementations of AI could explicitly account for differences in gender, ethnicity, etc., aiming for more effective treatments tailored to these groups. This approach can be seen as promoting "desirable bias," which mitigates undesirable biases and aligns with the objectives of P5 medicine.

Trust–An Evolving Relationship:

The dynamic between patients and healthcare professionals has evolved over time, and AI is poised to influence this relationship. While AI and robotics demonstrate proficiency, human oversight remains crucial. Robots and AI algorithms operate rationally, yet healthcare often demands empathetic responses. If doctors adeptly integrate AI into their practice, they can uphold the trust associated with their role. However, many patients, lacking in-depth understanding of these technologies, may struggle to trust AI [25] Conversely, when physicians effectively utilize AI and robotics for accurate diagnosis, beneficial treatment, and appropriate care, they can enhance patient trust [26].

CONCLUSION

AI technology is presently undergoing a remarkable revival and being applied to many domains. Health applications will both benefit from and contribute to further advances. There are many types of AI applications and robotic systems, which can be introduced in many aspects of health care. Over the last few years, a number of proof-of-concept and pilot projects that have exhibited promising results for diagnosis, treatment, and health maintenance. They have not yet been deployed at scale–in part because of the time it takes to fully evaluate their efficacy and safety.

The use of AI and robots in surgeries represents a groundbreaking shift in medical technology. These advancements allow for more precise operations, reduce the likelihood of human error, and lead to better results for patients. With the help of AI and robotics, surgeons can perform less invasive procedures and access real-time data, making complex surgeries easier to manage. As these technologies continue to grow, their presence in the operating room is set to increase, bringing even more efficiency and effectiveness to healthcare.

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