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INNOVATIVE ROBOTIC TECHNOLOGY AND ARTIFICIAL INTELLIGENCE IN PHARMACY AND MEDICINE – PAVING THE WAY FOR THE FUTURE HEALTHCARE

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ABSTRACT

Robotic technologies and artificial intelligence (AI) are revolutionizing the fields of pharmacy and medicine, driving innovations that enhance the efficiency, accuracy, and accessibility of healthcare services. In pharmacy, automation through robotics is streamlining drug dispensing, improving inventory management, and reducing human error, while AI-powered systems are enabling personalized medicine by analyzing patient data to recommend tailored therapies. In medicine, AI and robotics are transforming diagnostics, surgical procedures, and patient monitoring, facilitating early disease detection, minimally invasive surgeries, and real-time health tracking. The integration of AI in drug discovery and clinical trials is accelerating the development of new treatments, while robotic surgery is enhancing precision and recovery times. These technologies not only promise to improve patient outcomes but also to address global healthcare challenges, including shortages of skilled healthcare professionals and disparities in care access. As these advancements continue to evolve, they hold the potential to redefine the future of healthcare, making it more patient-centered, efficient, and sustainable.

KEYWORDS:- Robotic technologies & Artificial intelligence in Pharmacy and Medicine, Robotic Technologies in Pharmaceutical Manufacturing, Healthcare innovation, personalized Medicine, Robotic Surgery.

INTRODUCTION

The integration of robotic technologies and artificial intelligence (AI) in pharmacy and medicine is rapidly transforming healthcare, creating a new era of precision, efficiency, and personalized care. These innovations hold the potential to revolutionize traditional practices, enhancing patient outcomes, optimizing workflows, and reducing costs. Robotics is streamlining tasks such as medication dispensing, surgery, and rehabilitation, while AI is enabling faster diagnosis, predictive analytics, and personalized treatment plans.[1]

Together, these technologies are not only improving the quality of healthcare services but also empowering professionals to focus on more complex and human-centered aspects of care. As we move into the future, the continued evolution of robotic and AI-driven solutions promises to make healthcare more accessible, accurate, and effective, paving the way for smarter, more efficient systems in patient care, drug development, and clinical practices.[2,3]

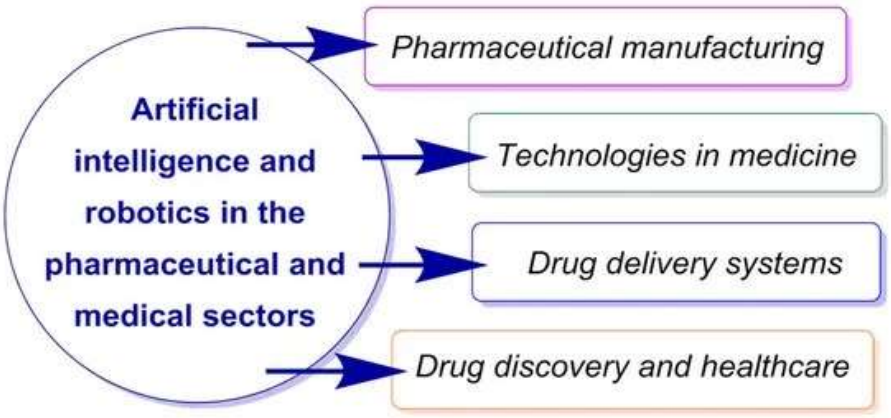


Fig. 1:- Robotic Technologies and Artificial intelligence in the Pharmaceutical and medical sectors.[41]

1) Robotic technologies in Pharmacy and Medicine

Robotic technology in pharmacy primarily focuses on improving the accuracy, efficiency, and safety of drug dispensing, compounding, and administration. In medicine, robots are used in surgeries, rehabilitation, and drug delivery systems.

Pharmacy applications

- **Automated dispensing systems:** Robotics are used in pharmacies to automate the medication dispensing process, reducing the risk of human error. These systems can quickly and accurately prepare prescriptions, increasing workflow efficiency.

- **Example:** The Swisslog system and McKesson's robotic dispensing systems automate the storage and retrieval of medications, reducing the workload on pharmacists and increasing dispensing speed (Zuniga et al., 2020).[4]

- **Compounding robots:** These robots are employed for compounding personalized medications, such as sterile injectables. They ensure precise doses and help maintain sterility in pharmaceutical preparations.

- **Example:** The Aprecia Pharmacy Services platform uses 3D printing technology for creating personalized, precise doses of medications, especially for pediatric and geriatric patients (Brennan et al., 2019).[5]

Medical applications

- **Surgical robots:** In surgery, robotic systems like da Vinci assist surgeons in performing minimally invasive procedures with greater precision and reduced recovery times.

- **Example:** The da Vinci Surgical System allows surgeons to perform complex surgeries with high precision using robotic arms controlled by a console, enhancing accuracy and reducing patient recovery time (Mouret et al., 2001).[6]

- **Robotic Prosthetics and Rehabilitation:** Robots are also used in rehabilitation, assisting patients in regaining motor functions post-injury or stroke. Advanced prosthetics can now be controlled by the brain or through AI algorithms to better respond to patient needs.

- **Example:** The ReWalk robotic exoskeleton assists individuals with lower-limb disabilities by allowing them to walk with the aid of robotic assistance.

2) Artificial intelligence in Pharmacy and Medicine

AI in pharmacy and medicine aims to enhance decision-making, predict patient outcomes, personalize treatment, and optimize drug development processes.

Pharmacy applications

- **AI in drug discovery:** AI algorithms are being used to analyze large datasets for the discovery of new drugs, speeding up the development process and identifying potential candidates for clinical trials.

- **Example:** IBM Watson has been used to analyze vast databases of clinical and molecular data to identify potential drug candidates for various diseases, including cancer (Mundt et al., 2020).[7]

- **Personalized Medicine and Pharmacogenomics:** AI algorithms can analyze patient genetic information to predict how they will respond to different drugs, enabling personalized treatment plans and improving therapeutic outcomes.

- **Example:** Tempus uses AI and machine learning to analyze clinical and molecular data, helping oncologists tailor personalized cancer treatments based on genetic markers (Mackay et al., 2020).[8]

Medical applications

- **AI in diagnostics:** AI algorithms can analyze medical imaging (such as CT scans, MRIs, and X-rays) to detect abnormalities, often with a level of accuracy comparable to or exceeding human radiologists.

- **Example:** Google's DeepMind developed AI that can detect over 50 eye diseases with the same accuracy as expert clinicians by analyzing retinal scans (De Fauw et al., 2018).[9]

- **Predictive Analytics and Decision Support:** AI tools are used in predictive analytics to forecast patient outcomes, such as predicting the likelihood of readmission, or even anticipating complications in patients with chronic diseases like diabetes or heart disease.

- **Example:** Aidoc, an AI company, provides tools that analyze radiological images and assist clinicians in diagnosing conditions like brain hemorrhages or cervical spine fractures more accurately and quickly (Muehlematter et al., 2020).[10]

Challenges and Ethical Considerations

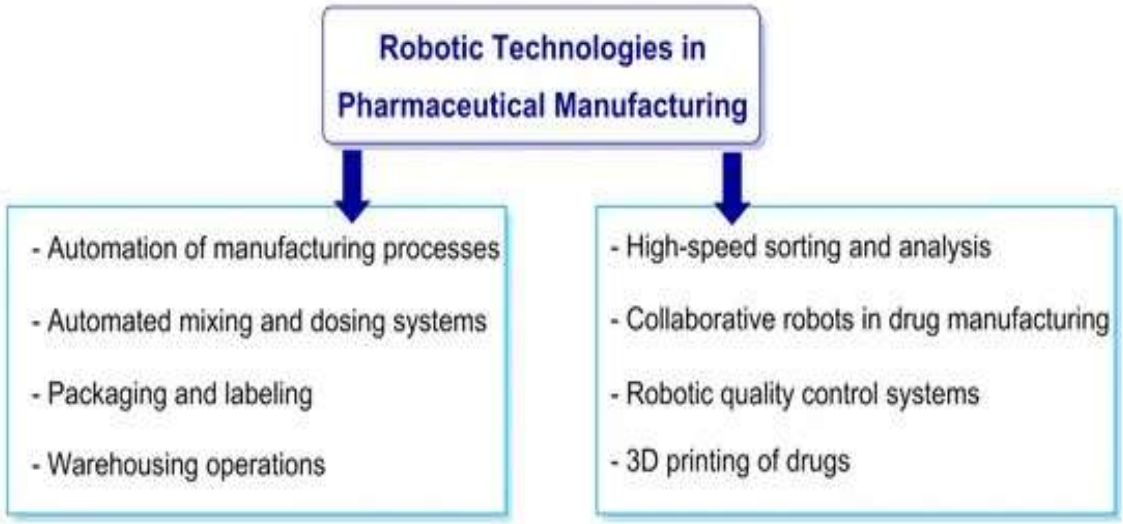
- **Ethical issues:** Both robotic technology and AI in healthcare raise ethical concerns, including patient privacy, data security, and the potential for biases in AI models, which could lead to inequities in care delivery.

- **Regulation and Safety:** Regulatory bodies like the FDA must ensure the safety and efficacy of AI systems and robotic devices used in medicine, which can be a slow and

complex process. The regulation of AI in healthcare is evolving, and there is a growing need for standards to ensure the safety of both patients and healthcare providers.

3) Robotic technologies in pharmaceutical manufacturing

Robotic technology in pharmaceutical manufacturing plays a critical role in enhancing productivity, ensuring precision, and improving safety. The adoption of robots helps streamline operations, reduce human error, and meet the high standards required in drug production and packaging. Below are key areas where robotic technology is being used in the pharmaceutical manufacturing sector:



1. Automated packaging

Robots are increasingly being used for packaging pharmaceutical products, including tablet and vial filling, blister packaging, and labeling. This enhances throughput, lowers the chance of contamination, and guarantees uniformity. Automated packaging systems are also beneficial for handling small batch production, which is becoming more common in the pharmaceutical industry due to personalized medicine.[11]

2. Material Handling and Sorting

Robotic arms are employed in the pharmaceutical industry to handle raw materials, intermediate products, and final products. Robots can transport materials between different parts of the facility, improving efficiency in a sterile environment, and reducing the risk of contamination.[12]

3. Quality Control and Inspection

Robots with sophisticated cameras and sensors are used in quality control procedures. These robots perform inspections for defects or contamination, ensuring that the pharmaceutical products meet strict regulatory standards. Automated visual inspection systems are used for detecting packaging defects, checking label accuracy, and performing batch verification.[13]

4. Sterile manufacturing

In highly regulated environments, such as the production of vaccines or biologics, robotic systems are employed to perform tasks like aseptic filling and sterile handling of products. Robots work in cleanrooms, ensuring high precision while maintaining sterility in the manufacturing process.[14]

5. Drug Development and Research

Robotic systems are also playing a key role in research and development for new drug formulations. High-throughput screening robots allow for the rapid testing of compounds to find effective drug candidates. These robots automate repetitive tasks, improving the efficiency of drug discovery processes.[15]

6. Robotics in cleanroom environments

The pharmaceutical industry requires highly controlled environments, especially in the production of sterile drugs. Robotics play a crucial role in cleanroom environments by reducing human intervention, thus minimizing the risk of contamination and improving overall production efficiency.[16]

Challenges and Considerations

While robotic systems provide several benefits, there are challenges related to the high initial investment costs, system integration, and ongoing maintenance. Additionally, ensuring robots meet regulatory requirements such as Good Manufacturing Practices (GMP) is critical for successful implementation.[17]

4) Healthcare innovation

Robotic technology and artificial intelligence (AI) are playing transformative roles in the healthcare sector, particularly in pharmacy and medicine. These technologies are improving operational efficiency, enhancing patient outcomes, and enabling the development of

personalized treatments. Below is an exploration of the applications of robotics and AI in pharmacy and medicine, supported by relevant references.

1. AI in Drug Discovery and Development

AI algorithms are being used to analyze vast datasets to discover potential drug candidates. By leveraging machine learning (ML) and deep learning (DL) models, AI can predict molecular behavior, optimize chemical structures, and identify biomarkers. This speeds up the drug discovery process, which often takes years.

Example applications

- **Predictive modeling:** AI models can predict which compounds will be effective against specific diseases, reducing the trial-and-error process in drug development.

- **Drug repurposing:** AI can identify existing drugs that may be repurposed to treat new conditions.[18]

2. AI in personalized medicine

AI allows healthcare providers to deliver more tailored treatments based on individual genetic profiles, lifestyle, and environmental factors. By analyzing patient data from genomics, medical records, and wearable devices, AI helps predict disease progression and optimize drug dosages for better therapeutic outcomes.

Example applications

- **Genomics and Precision medicine:** AI models can analyze large-scale genetic data to identify mutations and predict how patients will respond to specific treatments.

- **Personalized treatment plans:** AI can recommend personalized therapies based on real-time patient data.[19]

3. Robotic Surgery and Assistance

Robotic-assisted surgery is a type of minimally invasive surgery where surgeons use robotic systems to perform procedures with more precision, flexibility, and control than traditional methods. A robotic arm precisely does the surgery while the surgeon operates the robotic equipment, usually via a console. Robots equipped with AI assist surgeons by offering real-time data, analyzing medical images, and enabling fine motor control during surgeries. Robotics is particularly useful in areas like orthopedics, urology, and neurosurgery.

Example applications

- **Minimally invasive surgery:** Robotic arms, such as the Da Vinci Surgical System, allow surgeons to perform complex surgeries with greater precision and smaller incisions, reducing recovery times for patients.

- **Surgical assistance:** AI can help guide robotic systems in real-time by processing medical imaging data, offering potential improvements in surgical outcomes.[20]

4. Artificial intelligence in pharmacy: Automated dispensing systems

AI-driven automated dispensing systems are transforming the way pharmacies operate. These systems are designed to fill prescriptions, track inventory, and ensure accuracy, significantly reducing medication errors and improving efficiency. In hospital settings, robots are also used for compounding medications.

Example applications

- **Robot-Assisted dispensing:** Pharmacies use robots like the Parata Max or ScriptPro to automate the process of filling prescriptions, improving both accuracy and speed.

- **Inventory management:** AI helps track inventory levels, predict demand for drugs, and prevent shortages or expirations.[21]

5. AI and Robotics in Patient Monitoring and Care

AI algorithms can process data from wearable devices, sensors, and electronic health records to monitor patient conditions in real-time. Combined with robotic technologies, AI can help deliver personalized interventions, alert healthcare providers to critical changes in a patient's condition, and improve long-term care management.

Example applications

- **Remote patient monitoring:** AI-enabled wearable devices monitor patients' vital signs and alert healthcare providers if abnormalities are detected.

- **Robotic care assistants:** Robots like PARO (a therapeutic robotic seal) are used in geriatric care to provide companionship and support cognitive and emotional well-being.[22]

6. AI in Diagnostics

AI-driven diagnostic technologies are increasing disease detection speed and accuracy. Machine learning models are trained on vast datasets to analyze medical images (e.g., X-rays, CT scans, MRIs) and detect abnormalities such as tumors or fractures. AI also helps in analyzing lab results and identifying potential health issues earlier.

Example applications

- **Radiology AI Tools:** Algorithms like Google Health's AI for breast cancer detection or Aidoc's AI for radiology assist doctors by analyzing medical imaging scans for abnormalities.

- **Predictive diagnostics:** AI tools help predict diseases like cancer, diabetes, and heart disease through early detection algorithms based on patient data.[23]

7. AI Chatbots and Virtual assistants

AI-powered chatbots are being used in pharmacies and healthcare settings to provide information, answer patient questions, and assist with medication management. These virtual assistants can handle basic inquiries, offer drug interaction alerts, and help schedule appointments.

Example applications

- **Medication management:** AI chatbots remind patients to take their medications, help with refills, and provide educational content about their prescriptions.

- **Telemedicine virtual assistants:** AI-powered virtual assistants are used for preliminary consultations and providing follow-up care.[24]

8. Robotics in drug compounding

Robotic systems are used in hospitals and pharmacies to compound drugs, particularly for sterile preparations. These systems reduce human error, enhance precision, and ensure that drugs are compounded in a controlled environment.

Example applications

- **Sterile compounding robots:** Robots like the ROBOMED system are designed to automate the preparation of injectable medications in sterile environments.

- **Pharmacy automation systems:** Automated systems streamline the compounding process, improving efficiency and reducing the risk of contamination.[25]

5) Robotic technologies in personalized medicine

Robotic technology and artificial intelligence (AI) are increasingly transforming the pharmacy and medicine sectors, ushering in a new era of healthcare that promises efficiency, accuracy, and improved patient outcomes. Here's a look at how these technologies are shaping the future of healthcare, particularly in pharmacy and medicine packing:

1. **Robotics in pharmacy:-** Robots are being integrated into pharmacies to automate a variety of tasks, enhancing efficiency and accuracy. Pharmacy robots can assist in medication dispensing, inventory management, and even patient consultation.

- **Automated dispensing systems:** Automated dispensing robots are already in use to quickly and accurately dispense medications. These robots are capable of reducing human errors that can occur during the dispensing process. This technology ensures that patients receive the correct dosage, reducing medication errors and improving patient safety. An example is the ScriptPro Pharmacy Automation System, which offers robotic solutions for prescription dispensing and medication storage (Source: ScriptPro).

- **Robotic prescription filling:** Robots like RoboPharma and Omnicell are streamlining the prescription filling process. These systems can manage medication storage, retrieve medications, and even label them, freeing up pharmacists to focus on more critical tasks like patient care and consultation (Source: Omnicell).

- **Clinical decision support:** AI-powered robotic systems can also assist pharmacists by providing clinical decision support, analyzing patient data, and suggesting the most effective medications. These systems help reduce the likelihood of medication errors, particularly in complex cases where multiple medications are prescribed.[26]

2. Artificial intelligence in medicine packing

AI plays a crucial role in automating the packing process of medications, ensuring consistency and efficiency while minimizing errors.

- **AI and Machine vision for packaging:** AI-driven systems, coupled with machine vision, can inspect each package for accuracy. These systems can identify discrepancies such as incorrect labeling, packaging, or dosing errors before medications reach the patient. This significantly improves product quality and reduces the risk of human error.

- **Customized medication packaging:** AI is also being used in personalized medicine packaging. Adheris Health, for example, uses AI to offer blister pack solutions that help patients adhere to prescribed medication schedules by customizing packaging based on individual treatment regimens (Source: Adheris Health).

- **Robotics in medication Dispensing and Packaging:** Robotic systems are increasingly used to automate the process of packing medications in blister packs or bottles. Robots are capable of sorting and packing various types of medications in large volumes with minimal human intervention, ensuring efficiency and reducing labor costs.[27]

3. AI and Robotics in medication safety

Medication safety is a critical concern, and AI-driven technologies are playing a pivotal role in reducing medication errors.

- **Error Detection and Prevention:** AI can track patient data, such as medical history, allergies, and other prescriptions, to alert pharmacists and healthcare providers about potential drug interactions or side effects. This assists in ensuring safe medication practices.

- **AI in Pharmacovigilance:** AI algorithms are being used in pharmacovigilance to monitor and analyze adverse drug reactions (ADRs). By analyzing large datasets, AI systems can detect patterns of drug-related problems earlier and more accurately than traditional methods, which can lead to faster intervention and better patient care.[28]

4. AI in the Discovery and Development of drugs

AI and robotics are not limited to the dispensing and packing stages; they are also critical in drug discovery and development, shortening timelines and reducing costs in bringing new medications to market.

- **Predictive models for drug development:** AI algorithms are helping researchers predict how new drugs will behave in the body, identify potential side effects, and find more effective formulations. New treatments and therapies are being developed more quickly as a result.

- **Robotics in High-Throughput Screening:** Robots are used to automate the process of testing potential drug compounds in high-throughput screening (HTS) facilities. These

robotic systems can test thousands of compounds for effectiveness and safety, drastically speeding up the drug discovery process.[29]

5. Impact on healthcare workforce

While the integration of robotics and AI in pharmacy and medicine packing improves efficiency and accuracy, it also presents challenges and opportunities for the healthcare workforce. However, there may be concerns about job displacement, which calls for workforce retraining programs to ensure that employees can transition into more advanced roles in patient care or technology management.[30]

6) Robotic technologies in surgery

Robotic technology has revolutionized modern surgery by improving precision, reducing human error, and enhancing recovery times for patients. The integration of robotic systems into surgery allows surgeons to perform minimally invasive procedures with greater accuracy, control, and flexibility. Among the main advantages of robotic surgery are:

- **Minimally invasive procedures:** Robots allow for smaller incisions, reducing trauma to the body and minimizing scarring.
- **Enhanced precision:** Robotic systems provide better visualization and precision, especially in complex procedures.
- **Reduced recovery time:** Due to smaller incisions and less tissue damage, patients often experience faster recovery and less pain.
- **Improved ergonomics for surgeons:** Robotic systems reduce physical strain on surgeons during long procedures, leading to better outcomes.[31]

Fig. 3:- Robotic technologies in surgery.[43]

- **Types of robotic surgery**

1. Da vinci surgical system

The most well-known and widely used robotic system in surgery. The Da Vinci system includes a patient-side cart that stores equipment and a station where the surgeon may precisely control robotic arms. It is used in various types of surgery, including:

Urologic surgery (e.g., prostatectomy)

Gynecologic surgery (e.g., hysterectomy)

Cardiothoracic surgery (e.g., heart valve repair)

General surgery (e.g., cholecystectomy, colorectal surgery) (32)

2. MAKO Robotic-Arm Assisted Surgery

Used primarily for orthopedic procedures, the MAKO system employs robotic arms to assist in joint replacement surgeries, particularly hip and knee replacements. The system uses pre-operative imaging to create a personalized plan and ensure precise placement of the implants.

3. RAS (Robot-Assisted Surgery)

This includes various robotic systems, often integrated with laparoscopic techniques. RAS is used for procedures like laparoscopic cholecystectomy, bariatric surgery, and spinal surgery, enhancing surgeon control while performing delicate procedures.

4. CyberKnife

A non-invasive system used primarily in radiation therapy rather than direct surgery. It provides highly focused radiation for tumors, particularly in the brain, spine, and prostate. The system can move around the patient and adjust in real-time for precise delivery of radiation.

5. Versius surgical robot

A newer robotic system, similar to Da Vinci but with a modular design. It's used for general surgery and urological procedures. Its lightweight, compact design allows for flexibility and easier access to patients in varied surgical settings.

6. Navio surgical system

Focused on orthopedic surgeries, the Navio system helps with knee and hip replacements. To design and carry out the exact placement of implants, it incorporates 3D imaging.[33]

- **Types of surgery enhanced by robotics**

1) **Urological surgery:-** Robotic technology is frequently used in procedures like robotic prostatectomy (Removal of the prostate in prostate cancer), nephrectomy (Kidney removal), and bladder surgery.

2) **Gynecological surgery:-** In gynecology, robotic systems are employed for procedures like hysterectomy, myomectomy (Removal of fibroids), and pelvic organ prolapse surgery.

3) **Cardiac surgery:-** Robotic surgery assists in minimally invasive heart surgeries, such as valve repair and coronary artery bypass grafting (CABG), improving precision in delicate procedures.[34]

4) **Orthopedic surgery:-** Robotic technology is widely used in joint replacement surgeries like knee, hip, and shoulder replacements. Robotic systems like MAKO and Navio ensure better alignment of prosthetics and improve patient outcomes.

5) **Neurosurgery:-** Robotic systems such as NeuroArm help in delicate brain and spine surgeries. These robots provide enhanced precision for deep brain stimulation, tumor resection, and spinal surgeries.

6) **General surgery:-** Robotic systems assist in a wide range of procedures, including laparoscopic cholecystectomy (Gallbladder removal), colorectal surgeries, and bariatric surgeries. The precision and reduced risk of complications are significant benefits in general surgery.[35]

Merits of robotic surgery

- **Increased Precision and Accuracy:-** Robotic systems allow for highly precise movements, reducing the likelihood of errors in delicate surgeries. Surgeons can make smaller, more accurate incisions, which is crucial in complex procedures.

- **Minimally invasive approach:-** Robotic surgery often requires smaller incisions than traditional methods, leading to reduced tissue trauma, lower infection risks, and less scarring.

- **Reduced blood loss:-** The enhanced precision of robotic surgery minimizes the chance of cutting blood vessels, leading to less blood loss during surgery, which is particularly important in delicate operations.

- **Shorter recovery time:-** Because the surgeries are less invasive, patients experience less pain, shorter hospital stays, and faster recovery, enabling them to return to their normal activities more quickly.

- **Enhanced visualization:-** Robotic systems offer high-definition, 3D visualization, providing surgeons with a more detailed view of the surgical site, which helps in navigating complex anatomical structures.

- **Greater Control and Stability:-** Robotic arms provide greater stability and control than the human hand, especially in delicate or repetitive movements, improving outcomes in surgeries that require fine motor skills.

- **Better surgical outcomes:-** By reducing the chance of human error and providing real-time feedback, robotic surgery can contribute to better surgical outcomes, fewer complications, and lower rates of infection.

Demerits of robotic surgery

- **High cost:** Robotic surgical systems are expensive to acquire, maintain, and operate. The initial investment in robotic equipment and the associated maintenance costs can be prohibitively high for many healthcare facilities, especially in lower-resource settings.

- **Complexity and Learning curve:** Robotic surgery requires specialized training for surgeons, which can be time-consuming and may take some time to master. This learning curve can impact surgical outcomes during the initial adoption phase.

- **Technical Malfunctions and Limitations:** Robotic systems are highly dependent on technology, and malfunctions can occur during procedures. Issues such as software glitches, hardware failures, or loss of signal can disrupt surgery, potentially jeopardizing patient safety.

- **Reduced tactile feedback:** Unlike traditional open surgery, robotic systems may provide limited tactile feedback, which could make it more difficult for surgeons to feel the tissue or gauge certain physical conditions, potentially affecting the precision of the procedure.

- **Limited range of procedures:** While robotic surgery is highly effective in certain specialties (e.g., urology, gynecology, and some orthopedic surgeries), it is not suitable for all types of surgery, particularly those requiring more complex or rapid decision-making that might not align with robotic systems' capabilities.

- **Dependence on connectivity:** Robotic surgery systems often rely on stable internet and network connections. In regions with unreliable internet or power supplies, this could be a significant hindrance to effective use.

- **Increased time for setup:** Preparing a robotic surgery system for an operation can take longer than traditional procedures, increasing the overall time needed for surgery. This can impact scheduling and the number of surgeries performed in a given day.

- **Potential for reduced human interaction:** The use of robotic systems might lead to a reduced role for the surgeon in direct patient interaction during the procedure. While surgeons still control the robot, the physical distance from the patient could affect the surgeon-patient connection.

CONCLUSION

Robotic technologies and artificial intelligence (AI) are playing an increasingly transformative role in the fields of pharmacy and medicine, promising to enhance both the efficiency and the quality of healthcare delivery. Automation in the form of robotics is streamlining routine tasks such as medication dispensing, compounding, and drug storage, reducing human error and freeing up valuable time for healthcare professionals to engage in more critical and patient-focused activities. Meanwhile, AI algorithms and machine learning systems are advancing clinical decision-making, enabling personalized treatments, improving diagnostic accuracy, and accelerating drug discovery processes. These technologies are working together to create a more accurate, accessible, and efficient healthcare system in the future.

As we look toward the future, the integration of robotics and AI into healthcare systems will likely lead to a more holistic approach to patient care, with increased collaboration between machines and medical practitioners. However, challenges such as regulatory concerns, ethical considerations, and the need for continuous technological training must be addressed to maximize their potential benefits. Overall, these innovations are poised to revolutionize the way we approach healthcare, driving improvements in outcomes, reducing costs, and paving the way for a more patient-centric system.[36,37,38,39,40]

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- **Declaration of conflict**

The authors declare that they have no know competing financial intrests or personal relationships that could have appeared to influences the work reported in this paper.

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