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Position Paper

Title : Artificial intelligence (AI) revolutionizing healthcare, use of robots in treatment management, diagnostics, personalizing treatment, and improving patient care and satisfaction.

Abstract

Artificial Intelligence (AI) and robotics are revolutionizing healthcare by transforming how diseases are diagnosed, managed, and treated. This position paper explores the multifaceted applications of AI-powered robotics in diagnostics, surgical interventions, treatment management, and personalized medicine. AI enables data-driven, real-time decision-making, while robotics ensures precision and physical execution in clinical environments. Together, they reduce diagnostic errors, improve surgical outcomes, streamline treatment delivery, and elevate patient satisfaction. AI algorithms enhance medical imaging, identify biomarkers, and predict treatment outcomes, enabling early disease detection and tailored interventions. Robotics enhances surgical precision through systems like the da Vinci robot and aids rehabilitation via exoskeletons and socially assistive devices. Moreover, AI-driven pharmacy automation, elderly care support systems, and hospital logistics robots address operational bottlenecks and staff shortages, especially in resource-limited settings. Despite its promise, AI in healthcare raises concerns about patient autonomy, job displacement, data security, and algorithmic bias. This paper underscores the need for ethical governance, robust regulations, and interdisciplinary collaboration to maximize benefits while mitigating risks. The future of healthcare lies in intelligent, adaptive, and integrated systems where AI and robotics synergize to offer personalized, efficient, and accessible care. This paper advocates for strategic investments in AI and robotics infrastructure, particularly in developing health systems, to bridge gaps in care quality, access, and efficiency. By aligning innovation with patient-centric goals, healthcare can transition from reactive to predictive and personalized, fulfilling the promise of P5 medicine—predictive, preventive, personalized, participatory, and precise.

1.0 Introduction

1.1 Background

Artificial Intelligence (AI) is a rapidly evolving field of computer science that aims to create machines that can perform tasks that typically require human intelligence (Alowais et al., 2023) . AI includes various techniques such as machine learning (ML), deep learning (DL), and natural language processing (NLP). Large Language Models (LLMs) are a type of AI algorithm that uses deep learning techniques and massively large data sets to understand, summarize, generate, and predict new text-based content (Davenport and Kalakota , 2019 ; Suleimenov et al., 2020) .

AI has been used in healthcare settings to develop diagnostic tools and personalized treatment plans. As AI continues to evolve, it is crucial to ensure that it is developed responsibly and for the benefit of all (Jordan and Mitchell, 2015; Esteva et al., 2017; Topol, 2019). The incorporation of Artificial Intelligence (AI) in healthcare has been a gradual process, rooted in decades of technological progress. Initial forays into AI for medical purposes date back to the 1970s, exemplified by expert systems such as MYCIN, which were developed to aid in diagnosing bacterial infections (El_Jerjawi et al., 2024). However, these early systems were constrained by the computational limitations and the data availability of the time. It was not until the rise of big data, the advancement of machine learning algorithms, and the exponential increase in computing power that AI began to realize its full potential in the healthcare sector (Harazin and Abu-Naser, 2023; Harz et al., 2020).

Robotics, which is frequently considered to be a subfield of artificial intelligence, is playing an increasingly important role in patient care (Nessn et al., 2024) as indicated in Fig.1 . New technologies that are based on AI have been developed to predict there occurrence and progression of illness or the response to treatment. Within the realm of medicine, artificial intelligence (AI) refers to the practice of mimicking the decision-making procedures of medical professionals (Bajones et al., 2020; Bui & Chong, 2018)

While artificial intelligence is responsible for the generation of data, robotics is able to provide tangible results or carry out physical tasks (Nessn et al., 2024). The combination of artificial intelligence and robotics allows for a variety of tasks to be performed, including diagnosis, the planning of surgical procedures, the monitoring of patient physical and mental wellbeing, and the implementation of fundamental physical interventions to promote patient independence during the process of physical or mental deterioration (Routhier et al., 2021).

This position paper aim ed to examines the burgeoning influence of AI robotics in healthcare, encompassing various applications, benefits, challenges, and future prospects.

Fig. 1. AI and Robotics in Healthcare

Source: Ness et al.

1.2 Problem Statement

Traditional medicine (TM) is a collection of knowledge, skills and practices that the health maintenance as well as prevention, diagnosis, improvement for treatment of the physical and mental diseases (Mirzaeian et al., 2019). Traditional healthcare systems face several challenges that impact patient outcomes, operational efficiency, and overall satisfaction. These challenges include diagnostic errors, inefficiencies in healthcare delivery, information/data gathering, and patient dissatisfaction, all of which contribute to increased healthcare costs and compromised patient safety.

Diagnostic errors occur when a diagnosis is missed, incorrect, or delayed, leading to inappropriate treatment or adverse patient outcomes (Hall et al., 2020). Many diseases present with overlapping symptoms, making accurate diagnosis difficult. Cognitive biases and reliance on outdated diagnostic methods further exacerbate errors (Zwaan and Singh, 2015).

Healthcare inefficiencies arise due to administrative burdens, fragmented care, and outdated systems, leading to delays in treatment and increased operational costs (Herd and Moynihan, 2021).

Usage of the TM database effectively involves combining a huge amount of data from the database with the laboratory and clinical data, but this process is commonly hindered by some obstacles including the insufficient gathering of the data, the poor quality and nonhomogeneous data and the non-reproducibility of the available data (Bouin and Wierer , 2014; Zhang et al., 2016)

Another challenge reported for the development and promotion of TM is the lack of guidelines and protocols for the treatment and evaluation of safety and quality control (Mukherjee et al., 2015).

Developing a unique information system in TM capable of supporting a huge volume of nonhomogeneous data and information is considered as an intriguing issue in TM modernization (Wulamu et al., 2014; DeCapitani 2017).

Patient dissatisfaction stems from poor communication, lack of personalized care, and inadequate access to healthcare services (Ferreir et al., 2023).

These advancements are producing a revolution in the field of health care, making it possible for it to become proactive in accordance with the notion of P5 medicine, which is a discipline that follows the principles of being predictive, personalized, preventative, participative, and precise (Granić , 2022). AI has the potential to assist in the interpretation of personal health information in conjunction with other data in order to categories diseases in order to forecast, halt, or treat their progression (Iancu and Iancu, 2020).

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2 .0 AI in Healthcare: An Overview

2.1 AI and Robotics

The convergence of artificial intelligence (AI) and robotics has ushered in a new era of innovation in healthcare (Syed et al., 2019). AI-enabled robotic surgical systems have significantly transformed traditional surgical procedures. From minimally invasive surgeries to complex interventions, these systems offer unparalleled precision, dexterity, and control, thereby reducing surgical risks and improving patient outcomes. The integration of AI-powered robotics in telemedicine and remote patient monitoring has extended healthcare services beyond traditional clinical settings (Ness et al., 2024). Through telepresence robots and wearable devices, healthcare providers can remotely assess patients, monitor vital signs, and deliver timely interventions, especially in underserved or remote areas (Yang et al., 2020'; Zaza andAl -Emran, 2015). AI-driven robotic systems are increasingly utilized in rehabilitation therapies and assistive devices, catering to individuals with mobility impairments or neurological disorders (Zlatintsi et al., 2020).

AI-powered robotics play a pivotal role in diagnostic imaging, data analysis, and healthcare analytics, facilitating early disease detection, treatment planning, and predictive modeling (AlQudah et al., 2021). From image-guided interventions to radiology automation, these systems enhance diagnostic accuracy, streamline workflows, and optimize resource allocation (AlShamsi et al., 2022) robotics continue to proliferate in healthcare, it is imperative to address ethical concerns regarding patient privacy, algorithmic bias, and the human-AI interface (Mahn Do et al., 2018). Moreover, regulatory frameworks must adapt to ensure safety, efficacy, and equitable access to AI-driven healthcare technologies (Fernandes and Oliveira, 2021).

2.2 Current Applications

The integration of artificial intelligence (AI) and robotics has significantly transformed various industries, and healthcare is no exception (Manh Do et al., 2021) , as illustrated in Fig.2

Percentage of AI applications in different healthcare sectors

Source: Ness et al.

2.2.1 Medical Diagnosis

One of the most promising applications of AI and robotics in healthcare is in medical diagnosis. AI-powered robotics offer unparalleled precision and accuracy in medical diagnosis (Bakker and Budde, 2012; Mshali et al., 2018; Teeneti et al., 2021). Machine learning algorithms can analyze vast amounts of patient data, including medical records, imaging scans, and genetic information, to identify patterns and make accurate diagnostic predictions (Ness et al., 2024).

Robotic systems equipped with AI algorithms can assist healthcare professionals in interpreting diagnostic tests with greater speed and accuracy, reducing the risk of human error and misdiagnosis (De Togni et al., 2021). The integration of robotics in medical diagnosis streamlines the diagnostic process, leading to faster results and improved patient care (Woodie, 2015). Automated robotic systems can perform diagnostic procedures such as imaging scans, laboratory tests, and sample analysis with minimal human intervention. This not only accelerates the diagnosis but also frees up healthcare professionals to focus on patient care and treatment planning. AI-driven robotics enable personalized medicine by analyzing individual patient data to tailor diagnostic and treatment approaches (Aymerich-Franch, 2020; Borup et al., 2006).

By leveraging machine learning algorithms, robotic systems can identify unique biomarkers, genetic predispositions, and treatment responses, allowing for precision medicine interventions. This personalized approach enhances diagnostic accuracy and therapeutic efficacy, ultimately improving patient outcomes and reducing healthcare costs (Braun and Clarke, 2008). The combination of AI and robotics facilitates remote diagnostics and telemedicine, particularly in underserved or remote areas. Robotic systems equipped with AI algorithms can remotely collect patient data, perform diagnostic tests, and transmit results to healthcare professionals for analysis and interpretation (Brown and Baker, 2012). AI-driven robotics enable continuous monitoring of patient health parameters and real-time data analysis for predictive analytics. Robotic devices equipped with sensors and AI algorithms can monitor vital signs, physiological parameters, and disease markers, allowing for early detection of potential health complications (Brown and Michael, 2010). By predicting disease progression and identifying risk factors, these systems empower healthcare providers to intervene proactively, leading to better disease management and improved patient outcomes.

While AI-driven robotics hold tremendous potential in medical diagnosis, several challenges and considerations must be addressed (Brown et al., 2000). These include data privacy and security concerns, regulatory hurdles, ethical implications, and the need for ongoing validation and refinement of AI algorithms. Moreover, the integration of AI and robotics into existing healthcare infrastructure requires significant investment in training, infrastructure, and interoperability standards (Chin-Yee and Upshur, 2019).

2.2.2 Surgical Interventions

The integration of artificial intelligence (AI) and robotics in surgical interventions has revolutionized the field of medicine, enhancing precision, reducing human error, and improving patient outcomes (Coeckelbergh , 2020). Surgical robotics powered by AI algorithms have significantly augmented the capabilities of healthcare professionals, enabling them to perform complex procedures with unprecedented accuracy and efficiency (Erikainen and Chan, 2019). The convergence of AI and robotics has not only transformed the surgical landscape but also holds immense potential for further innovation in medical interventions (Eubanks, 2018).

AI-driven robotic systems offer submillimeter precision, surpassing the capabilities of human hands. This precision is particularly crucial in delicate procedures such as neurosurgery and ophthalmic surgery, where even minor errors can have severe consequences. Robotic-assisted surgeries facilitate minimally invasive techniques, reducing trauma, blood loss, and recovery time for patients (Fitzgerald, 2014). AI algorithms assist surgeons in navigating intricate anatomical structures with greater ease and accuracy, leading to smaller incisions and improved cosmetic outcomes (Fitzgerald, 2017). AI-enabled robotic platforms provide surgeons with real-time feedback during procedures, offering insights into tissue characteristics, vital signs, and procedural metrics. AI algorithms analyze patient data, including medical imaging, genomic information, and clinical history, to tailor surgical interventions to individual patients (Gardner and Williams, 2015). This personalized approach improves treatment efficacy, reduces complications, and enhances postoperative recovery. The high initial cost of robotic systems poses challenges to widespread adoption, particularly in resource-limited settings. Addressing cost barriers and ensuring equitable access to AI-driven surgical technologies remains a priority for healthcare stakeholders (Ness et al., 2024).

Effective training programs are essential to empower surgeons with the skills required to operate AI-driven robotic platforms proficiently. Continuous education and certification initiatives play a critical role in ensuring the safe and effective implementation of these technologies in clinical practice. As AI algorithms play an increasingly prominent role in surgical decision-making, ethical considerations regarding autonomy, accountability, and data privacy emerge. Clear guidelines and regulatory frameworks are needed to navigate these complex ethical and legal landscapes (Gardner and Williams, 2015). The future of surgical robotics lies in the convergence of AI, robotics, and other cutting-edge technologies such as augmented reality, telemedicine, and nanorobotics (Hall and Gill, 2019). Innovations in AI-driven autonomous systems, surgical simulation, and remote surgical capabilities hold promise for further enhancing surgical outcomes and expanding access to quality healthcare globally (Hedgecoe, 2003).

2.2.3 Cognitive Rehabilitation Aid

Rehabilitation encompasses a wide range of techniques and technologies aimed at restoring or enhancing physical and cognitive abilities in individuals who have suffered injuries or disabilities. Assistive robotics and cognitive rehabilitation aids play significant roles in this field, offering innovative solutions to improve therapy outcomes and enhance quality of life (Ness et al., 2024).

Exoskeletons: These wearable robotic devices can assist individuals with mobility impairments by providing support and guidance for limb movements. They are particularly useful for individuals recovering from stroke, spinal cord injuries, or musculoskeletal disorders (Hollis et al., 2019).

Robotic Gait Training : Robotic systems designed for gait training help individuals regain walking ability by providing repetitive and controlled movement patterns. These systems can adjust parameters such as speed, step length, and support levels based on the user's needs (Holm and Takala, 2007).

Robotic Arm Therapy : For individuals with upper limb impairments, robotic devices can assist in rehabilitation exercises aimed at improving arm function, strength, and coordination. These devices often offer interactive games and exercises to engage users and motivate them during therapy sessions (Ieva, 2019).

Virtual Reality (VR) Therapy : VR systems can create immersive environments to simulate real-world scenarios and challenges. In cognitive rehabilitation, VR technology is used to train cognitive skills such as attention, memory, problem-solving, and executive functions (Jecker, 2020).

Brain-Computer Interfaces (BCIs): BCIs enable direct communication between the brain and external devices, allowing individuals with severe motor disabilities to control computers or robotic systems using their brain signals. BCIs hold promise for cognitive rehabilitation by facilitating neurofeedback training and brain stimulation techniques (Lorenzini, 2018).

Mobile Applications and Gamified Platforms : Mobile apps and games designed specifically for cognitive rehabilitation offer engaging activities to improve memory, attention, language skills, and other cognitive functions. These platforms often use adaptive algorithms to tailor therapy tasks to the user's abilities and track progress over time (Mittelstadt et al., 2016).

Wearable Sensors : Wearable devices equipped with sensors can monitor movements, muscle activity, and vital signs during therapy sessions. Real-time feedback provided by these sensors allows therapists to adjust interventions and optimize rehabilitation protocols for each individual (Mohd, 2019).

Smart Rehabilitation Equipment : Advanced rehabilitation equipment embedded with sensors and actuators can adapt resistance levels, range of motion, and other parameters to provide personalized therapy experiences. These smart devices also collect data for performance monitoring and outcome assessment (Moreira and Palladino, 2005).

2.2.4 Drug Discovery

Robotics can be integrated with artificial intelligence (AI) and machine learning algorithms to analyze large datasets generated from screening assays. AI algorithms can identify patterns and correlations in complex biological data, assisting in the discovery of potential drug candidates (Noble, 2018).

2.2.5 Personalized Medicine

Robotics facilitates the screening of patient-derived cells or tissues to identify personalized treatment options. Automated systems can handle the complexities of personalized medicine, such as processing individual patient samples and testing them against various drug compounds or combinations (Pickersgill, 2011).

2.2.6 Cell Culture and Organoids

Robotic platforms enable the culture and manipulation of 3D cell models and organoids, which better mimic human physiology compared to traditional 2D cell cultures. This allows for more accurate drug screening and assessment of drug efficacy and toxicity (Schüll , 2016).

2.2.7 Precision Drug Delivery

Robotics can assist in precise drug delivery, particularly for targeted therapies or drug formulations. Automated systems can control drug dosing and delivery parameters with high accuracy, optimizing treatment outcomes while minimizing side effects (Tutton, 2011).

2.2.8 Integration with AI-driven Drug Design

Robotics can work in tandem with AI-driven drug design platforms to synthesize and test novel compounds rapidly. Automated synthesis and screening pipelines accelerate the iterative process of drug discovery and optimization (Vicsek, 2020).

3 .0 Significance of AI and Robotic

The influence of AI-powered robotics in healthcare is profound, offering a range of benefits that could potentially revolutionize the field (Kitchenham and Charters, 2007) and also illustrated in Fig.3 . AI-powered robots can perform tasks with a level of precision and consistency that surpasses human capabilities (Lanza et al., 2020). This is particularly crucial in surgeries where even slight errors can have significant consequences (Limosani et al., 2018). Robots can execute procedures with minimal invasiveness and higher accuracy, leading to reduced recovery times and improved patient outcomes. AI-driven robotics enable telemedicine and remote healthcare services extending medical expertise to areas with limited access to healthcare facilities (Lunardini et al., 2019). Remote robotic systems can be controlled by healthcare professionals from anywhere in the world, allowing them to perform surgeries or provide consultations without physically being present (Moher et al., 2009). Many regions face shortages of healthcare professionals, particularly in specialized fields such as surgery and eldercare.

AI-powered robots can alleviate this strain by assisting healthcare workers in various tasks, from assisting in surgeries to aiding with daily activities for the elderly or disabled (Osivue et al., 2018; Ozturk et al., 2020). By automating repetitive tasks and assisting in complex procedures, AI-driven robots can reduce the risk of human error. This enhances patient safety and minimizes the likelihood of adverse events during medical interventions (Ness et al., 2024). AI algorithms can analyze vast amounts of medical data to identify patterns, predict outcomes, and assist healthcare providers in making informed decisions (Saa et al., 2019). By integrating robotics with AI, these insights can be directly applied to patient care, leading to more personalized treatment plans and improved diagnoses (Saeed Sharif and Herghelegiu , 2018).

Robots equipped with AI algorithms can facilitate rehabilitation and physical therapy for patients recovering from injuries or surgeries. These robots can provide personalized exercises, track progress, and adjust therapy regimens in real-time based on the patient's response, enhancing the effectiveness of rehabilitation programs (Smutny and Schreiberova , 2020). While the initial investment in AI-powered robotics may be significant, the long-term cost benefits can be substantial. By streamlining processes, reducing hospital stays, and preventing complications, AI-driven robotics can ultimately lower healthcare costs and improve the efficiency of healthcare delivery (Suhail et al., 2022).

Fig. 3: Potential of AI and robotics in healthcare

Source: Ness et al/ (2024)

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4 .0 Application of AI Robotic in Healthcare

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4 .1 Use of Robots in Diagnostics

Robotic healthcare systems are becoming reliable, sustainable, accurate and beneficial to people than the conventional systems (Sehume and Markus, 2020). The poor patient to doctor ratio and inaccessibility to advanced healthcare systems are acute problems that the medical fraternity still faces. Robots have been tested and tried to solve these problems and the effort has been successful as robotic applications have evolved from simple day to day activities like cleaning and washing to performing critical surgeries on the heart and the brain (Lanfranco et al., 2004). The robotic system developed herein acts as a medium of communication between the patient and the doctor in case of physical absence of the doctor and also performs further medical tests that require more analysis which can be mobilized to the doctor and the patient. By employing this robotic medical assistance system, infection caused by human intervention in hospitals can be reduced considerably and more accurate measures will be used effectively (Sehume and Markus, 2020). Many robotic devices have been used in many medical interventions. For instance, robotic interaction can transcribe and store crucial medical information minimizing the possibility of error as well as helping doctors and nurses to early diagnose patients and even assisting lower-skilled people to administer operation with less input from higher-skilled personnel (Sehume and Markus, 2020).

Temperature

Body temperature is one of the critical measures of the health status of a patient. The Body temperature is typically, measured into three categories: hypothermia, which occurs when the body temperature is below 36.0 ◦ C; normothermia, which is the adequate range of 37.5 ◦C to 36.5 ◦C for the human body; and hyperthermia, which occurs when the body temperature exceeds 37.5 ◦C. Hypothermia is regarded as a potentially fatal emergency condition, and it is possible that even coma could occur if it is not treated quickly. Hyperthermia is a raised body temperature due to failed thermoregulation, a situation that may cause organ damage or death (Panagiotis et al., 2005).

Heart Rate

The heart rate (HR) is another measure of patient health. In fact, evidence of high HR variability can support diagnoses such as infection, high levels of triglycerides or cholesterol, and lethal arrhythmias (Kranjec et al., 2015). Some researcher's shows that they are able to measure the patient's HR through a non-invasive photoplethysmographic (Pancar et al., 2014). The system detects the heart beats per minute (BPM) and normal-to-normal heartbeat intervals (N-N intervals) from a continuous ECG wave record. Conventionally, the time at which the photoplethysmographic pulse waveform reaches 50% of its maximum value is used to indicate the beginning of a pulse (Jadav and Sitapra , 2013). The N-N interval is the elapsed time between pulses.

Diabetes

Diabetes is a disease that results from abnormal levels of insulin in the body, due to either a malfunction of the pancreas not producing enough insulin or the cells in the body not using it adequately (Haffner, 2003). The studies show that managing diabetes is complicated when diagnosed late, and that is the main problem for most people. In South Africa there is application of Non-invasive Interactive Robotic Medical Assist System (NIRMAS) for early diagnostics to advance healthcare system (Sehume and Markus, 2020).

4.2 Robots in Treatment Management

Chronic pain treatment is complex and multifaceted, and the application of technology to aid in self-management at home may benefit pain patients by assisting with daily routines, providing soothing sensations or mimicking physical therapy (PT) (Heapy et al., 2015). Additionally, those experiencing acute pain in a medical setting, such as a painful procedure, may benefit from technological methods that lessen pain and lead to better outcomes (Gates et al., 2020). Generally , interventions use one of three existing theoretical approaches to pain management: pain distraction (Hawthorn and Redmond, 1999), pain gating or cutaneous stimulation (Bedwell et al., 2011; Ellingsen et al., 2016; Gallace and Spence, 2010), and affective touch (Higgins et al., 2022).

Robotics technologies have already been imagined, researched and deployed in a variety of healthcare scenarios, and it is hoped that robotics will become integrated into a patient's healthcare journey (Khan and Anwar, 2019). pain management research uses a socially assistive robot (SAR), that provides assistance through social interaction including dialogue, sounds and gestures, rather than providing physical assistance (Feil-Seifer and Matarić, 2005). This utilises human-robot interaction (HRI) to distract or relax a patient undergoing a procedure or therapeutic regimen. Research into SARs and HRI has already shown potential uses in healthcare, particularly the care of people in later life, providing assistance, therapy or comfort and improving quality of life (Abdi et al., 2018).

One of the most common methods to manage pain using robots was distraction, often using NAO performing a routine (Alemi et al. 2016; Ali et al, 2021; Beran et al. 2013; Farrier et al. 2019; Jibb et al. 2018; Manaloor et al. 2019). SARs were pre-programmed or operator-controlled to provide interactions that included performing for the child, to put attention on the robot and away from the procedure at hand.

Pain itself can be difficult to measure, as one person's perceptions and tolerance can be different from the next (Chapman et al., 1985). Frequent measurements of pain included the self-reported Wong-Baker FACES pain rating scale or Faces Pain Scale –Revised (FSP-R) (Hicks et al., 2001). Alternative self-report measurements included the visual analogue scale (VAS) for pain (Langley and Sheppeard, 1985). Others used self-reported measurements relating to pain anxiety or behaviours such as the Multidimensional Anxiety Scale for Children (MASC) (March et al., 1997) or their own interviews or questionnaires (Higgins et al., 2022).

4.3 Personalizing Treatment with AI

The idea of personalized medicine, which customises treatment to a single patient according to their unique traits, has been a longstanding aspiration in the healthcare sector (Alum and Ugwu, 2025). Artificial intelligence (AI) has actualized this aspiration through technological advancements, promising to improve diagnosis and treatment. AI has profoundly changed the healthcare sector in terms of diagnosis, treatment, patient care, and accelerated drug discovery (Ugwu et al., 2024).

AI applications encompass several medical disciplines, including as cardiology, gastroenterology, and radiology, presenting opportunities for enhancements in disease detection, treatment strategies, and patient outcomes (Santoro et al., 2022; Stafie et al., 2023). Medical diagnosis applies deep learning models to images like artificial networks (ANN), magnetic resonance imaging (MRIs), computed tomography (CT) scans, and X-rays to detect diseases like cancer, heart diseases, and neurological diseases (Rana and Bhushan, 2023).

Several AI algorithms have been reported to enhance diagnostic efficiency, especially deep learning algorithms and machine learning (Parekh et al., 2023). The use of AI in image recognition can assist in identifying slight differences in the image captured through X-rays or MRI for the diagnosis of cancer, heart diseases, and neurological disorders (Alowais et al., 2023). AI can find some biomarkers associated with a specific disease and will help in the precise diagnosis and treatment of the patient (Karalis, 2024). Kumar et al. (2023) demonstrated that the application of AI in diagnosing these disorders yielded superior out-comes in prediction rate, accuracy, sensitivity, and specificity compared to conventional approaches. Chen et al. (2019) conducted a systematic review and meta-analysis assessing the application of artificial intelligence in the diagnosis, treatment, and outcome prediction of urologic disorders. They indicated that AI possessed greater advantages compared to conventional models and methodologies. They observed a reported AI superiority of 71.8% in diagnostic and outcome prediction (Chen et al., 2019). Keenan et al. (2021) tested how well retinal specialists could find retinal fluid in spectral domain OCT scans of eyes with age-related macular degeneration. They compared their performance to that of an AI algorithm. Retinal experts exhibited suboptimal accuracy and diminished sensitivity in identifying retinal fluid. This was especially applicable to intraretinal fluid and challenging instances, whereas AI-based detection attained superior accuracy, sensitivity, specificity, and precision (Keenan et al., 2021).

AI techniques are often employed to evaluate the patient's reaction to a specific therapy and select the optimal treatment regimen depending on the patient's genetic and clinical profile (Pushkaran and Arabi, 2024). This can be particularly important in oncology, as AI can assist in selecting the most effective chemotherapy or immunotherapy regimen based on the tumour's genomic characteristics. It can also monitor the patient's reaction to specific treatment and management plans and adjust them to meet the intended goals with minimal adverse outcomes. For example, the AI systems could use the data from the wearable and other digital health records to track the patient's state and recommend changes in the management plan (Yelne et al., 2023).

Technologies of AI such as artificial neural networks (ANN), deep learning models, and support vector machines, have proven useful in disease detection, diagnosis, and therapy optimisation during preclinical and clinical trials (Rezayi et al., 2022). In oncology, AI has effectively analysed genomic data, medication responses, and phenotypes, attaining great precision in personalised treatment strategies (Rezayi et al., 2022). Krittanawong et al. (2019) revealed in their clinical trials that the incorporation of AI in cardiovascular care is similarly promising, incorporating insights from oncology. To optimise the advantages of AI in personalised medicine, essential factors encompass the standardisation and aggregation of genetic and health data, the utilisation of multi-modal data, collaboration with disease specialists, scrutiny of AI findings by clinical communities, and extensive clinical trials to corroborate AI-derived insights (Gifari et al., 2021).

Drug discovery can be achieved using AI, where there is the possibility of predicting the efficacy and safety of the new drugs, identifying the targets of the drugs, and even designing the clinical trials (Dhudum et al., 2024). AI can help in genomic studies, clinical trials, and real-world evidence to identify molecules that will have the best chance of succeeding in the clinical development process (Chopra et al., 2023). Also, it can be applied in choosing patients for clinical trials based on genomics and proteomics to increase the chances of drug effectiveness and shorten the time taken to acquire approval (Singh et al., 2023).

4.4 Improving Patient Care and Satisfaction

The fusion of robots and AI stands as a significant breakthrough in an era of unheard-of technical developments, promising to revolutionize medical care in a variety of way (Margam, 2024).

Rehabilitation Robotics : This has become a ground-breaking discipline that has a significant influence on patients' physical treatment and rehabilitation for mobility disabilities. This area of robotics is committed to enhancing the lives of people who are having trouble recovering their independence and mobility. Notably, persons with lower limb impairments now have hope because to this technique (Willemink et al., 2020). Exoskeletons, revolutionary wearable technologies intended to offer essential assistance to people during walking and rehabilitation procedures are among the ground-breaking developments in rehabilitation robotics (Margam, 2024). Leading manufacturers of this technology, like Ekso Bionics and ReWalk, have made substantial advancements in improving patient lives. For instance, Ekso Bionics has created exoskeletons that patients can wear to aid in their recovery of movement (Esquenazi et al., 2012; Stearns-Yoder and Brenner, 2018). These gadgets provide patients who have lost their movement as a result of spinal cord injuries or other disorders fresh hope and confidence. Patients notice a considerable improvement in their mental wellbeing in addition to regaining physical strength when they perform activities like standing and walking (Fichtinger et al., 2022).

Robotic Surgery : Robotic-assisted surgery is a revolutionary development in the field of medicine that has completely changed how operations are carried out. With an emphasis on accuracy, safety, and minimally invasive procedures, this cutting-edge technology promises a paradigm leap from conventional surgery (Freschi et al., 2013). The da Vinci operating System's capacity to provide doctors unmatched flexibility and a three-dimensional visualization of the operating site is one of its main advantages(Fung et al., 2009) The da Vinci System's robotic arms offer an impressive range of motion and stability, in contrast to conventional surgery, where the surgeon's motions may be constrained by human variables including hand tremors and the constraints of the human wrist (Van Der Veen et al., 2018) The high-definition 3D visualization offered by the technology significantly improves surgical accuracy. Surgeons have great depth awareness and clarity while navigating intricate anatomical systems. They can recognize and work with delicate tissues and structures with a degree of accuracy that was previously unachievable because to this level of detail (Mayet et al., 2023). It is impossible to emphasize the benefits of robotic surgery for patient care (Velo and Minuz , 2009); Shorter hospital stays, less pain and suffering, and quicker recovery periods all result from less intrusive procedures.

Pharmacy Automation : Robotics is vital in expediting the complex operations of medicine manufacturing and distribution, making pharmacy automation a crucial innovation in the healthcare industry. The Aesynt created IV Robotic System, which stands as a ground-breaking solution for optimizing the compounding of intravenous (IV) drugs, is one of the famous examples of such technology integration(Qadan et al., 2014) Precision, safety, and the reduction of human error are the three main objectives of Aesynt's IV Robotic System, which represents a disruptive approach to the production of IV drugs(Mayor et al., 2022) This robotic system stands out as an example of contemporary pharmaceutical automation in the setting of sterile compounding, where careful precision is crucial. The effective simplification of pharmaceutical compounding processes is one of the main goals of the IV Robotic System (Kumprou et al., 2021). This technology is an example of the dedication to maximizing patient care since it prioritizes precision, reduces human error, and maintains cleanliness. With such automation, the pharmacy industry is well-positioned to advance the objectives of therapeutic excellence and pharmaceutical safety within the healthcare system (Margam, 2023).

Elderly care assistance : Robotics' incorporation into elderly care and support has resulted in a paradigm shift that has paved the way for creative solutions targeted at improving seniors' quality of life and wellbeing. The PARO therapy robot is one innovative example in the field of robotic companions for the elderly (Calo et al., 2011). This robotic creature, made to look like a newborn seal, is a symbol of the helpful and understanding role that robots may play in providing care for the elderly. Elderly people frequently experience loneliness and emotional anguish, especially those who live in long-term care institutions or are socially isolated. To lessen these emotional responsibilities, the PARO robot has been intelligently included into various situations (Cheng and Jiang, (2020). It is more accessible and charming to elders because of its physical similarity to a newborn seal, which develops a sense of familiarity and comfort. Giving older people company and emotional support is one of the PARO therapy robot's main goals (Kumar et al., 2023).

Hospital Logistics : The smooth delivery of treatment requires effective hospital logistics and supply chain management in the complicated and hectic environment of healthcare institutions. The TUG robot, created by Aethon, is one example of this technological revolution in action. A technological high point in hospital logistics and delivery is the TUG robot. Its main job is to automatically move supplies, lab samples, and drugs among hospitals, which improves the flow of vital resources throughout the healthcare system. The TUG robot's capability to independently explore hospital surroundings is a key component of its value proposition (Mirbabaie et al., 2021). It works around the clock to make sure that prescription drugs, supplies, and specimens are delivered on time and without delay (Jiang et al., 2017). Additionally, the robot minimizes idle time and lowers the possibility of supply chain backlogs in order to maximize resource utilization. The care and safety of patients are further improved by this proactive approach to logistics, which guarantees that essential supplies are accessible when needed (Lidströmer and Ashrafian , 2022). Implementing such technologies frequently results in considerable long-term cost savings for hospitals, enhancing the viability of healthcare operations (Fogel and Kvedar, 2018).

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5 Ethical and Practical Considerations

According to El_Jerjawi et al., (2024), the deployment of AI in healthcare brings significant ethical and social considerations:

Impact on Jobs in Healthcare : AI's ability to automate routine tasks and assist in complex decision-making could lead to shifts in the healthcare workforce. While AI may displace some jobs, it also has the potential to create new roles that require expertise in AI technology, data analysis, and human-AI interaction. Reskilling and upskilling programs will be essential to prepare the healthcare workforce for these changes and to ensure that AI complements rather than replaces human expertise.

Data Security : Ensuring the security of patient data is a major concern with the increased use of AI. The collection, storage, and analysis of vast amounts of sensitive health information heighten the risk of data breaches and misuse. Developing robust cybersecurity measures, implementing strict data governance policies, and ensuring compliance with data protection regulations are crucial for safeguarding patient privacy and maintaining trust in AI systems.

Patient Autonomy : AI's role in healthcare raises questions about patient autonomy and informed consent. As AI systems become more integrated into clinical decision-making, it is important that patients understand how these systems influence their care and ensure that their preferences and values are considered. Transparent communication about AI's role in healthcare decisions and maintaining patient involvement in treatment choices are essential to upholding patient autonomy.

Algorithmic Bias and Fairness: The risk of algorithmic bias remains a critical concern. Ensuring that AI systems are developed and tested with diverse and representative datasets is essential to preventing disparities in care. Ongoing efforts to audit and improve AI systems for fairness and equity will be necessary to address potential biases and promote equitable healthcare outcomes.

Accountability and Liability : Determining accountability in cases of errors or adverse outcomes involving AI robotics can be challenging. Clear guidelines and mechanisms for assigning responsibility and liability are necessary to ensure accountability and prevent harm to patients (Crossman et al., 2018) .

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6. Practical Challenges :

The integration of artificial intelligence (AI) and robotics has shown immense potential in transforming various industries, and healthcare is no exception (Ness et al., 2024). From surgical assistance to patient monitoring, AI robotics offers a range of applications that can significantly improve patient care and operational efficiency. However, this promising field also faces several technological hurdles and interoperability challenges that must be addressed to fully realize its benefits (Tronto , 2018).

Complexity of Healthcare Environment : Healthcare settings are dynamic and complex, presenting challenges for AI robotics systems to adapt effectively. Factors such as diverse patient populations, varying medical conditions, and the need for real-time decision-making require sophisticated AI algorithms and robotics capabilities (Tronto and Kohlen , 2018).

Safety and Reliability : Ensuring the safety and reliability of AI robotics systems is paramount in healthcare. Any malfunction or error could have serious consequences for patients. Developing robust safety mechanisms, fail-safes, and rigorous testing protocols are essential to mitigate risks (Vallès -Peris et al., 2021).

Integration with Existing Infrastructure : Healthcare facilities often have diverse legacy systems and equipment that may not be compatible with AI robotics technologies. Integrating new AI robotics solutions seamlessly into existing workflows and infrastructure requires careful planning and coordination (Anderson and Anderson, 2015).

Data Security and Privacy : AI robotics systems rely heavily on data, including sensitive patient information. Maintaining data security and privacy while enabling seamless data exchange between different components of the healthcare ecosystem is a significant challenge. Compliance with regulations such as HIPAA (Health Insurance Portability and Accountability Act) is essential (Bijker, 2009).

Human-Robot Interaction : Effective collaboration between AI robots and healthcare professionals is crucial for successful deployment. Designing intuitive user interfaces and ensuring natural interaction modalities are key considerations. Moreover, addressing concerns about job displacement and ensuring that AI robotics augment rather than replace human expertise is essential (Boada Pareto et al., 2021).

Standardization : Lack of standardized interfaces and protocols hinders interoperability between different AI robotics systems and healthcare devices. Establishing industry-wide standards for data exchange, communication protocols, and interoperable interfaces is essential to enable seamless integration and collaboration (Cabibihan et al., 2013).

Vendor Lock-In : Proprietary technologies and closed ecosystems from different vendors can create interoperability challenges, leading to vendor lock-in and limited flexibility for healthcare providers. Encouraging open-source initiatives and fostering collaboration between vendors can help mitigate these issues (Callon et al., 2009).

Interoperability Across Healthcare Ecosystem : Healthcare delivery involves various stakeholders, including hospitals, clinics, laboratories, pharmacies, and medical device manufacturers. Achieving interoperability across this diverse ecosystem requires addressing differences in data formats, communication protocols, and workflow integration (Callon and Latour, 1992).

Regulatory Compliance : Regulatory requirements related to data sharing, patient consent, and healthcare standards vary across jurisdictions. Ensuring interoperability while complying with these regulations poses additional challenges. Harmonizing regulatory frameworks and promoting interoperability-friendly policies can facilitate compliance (Clarke and Braun, 2014).

Data Exchange and Integration : Effective data exchange and integration between AI robotics systems and electronic health record (EHR) systems are critical for providing comprehensive patient care. However, disparate data formats, semantic interoperability issues, and data silos hinder seamless information exchange. Implementing interoperable data standards and interoperability frameworks can facilitate efficient data exchange and integration (Cockburn, 2005).

7. 0 Position Thoughts on AI Robotic in Healthcare

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1. AI-Driven Diagnostics Improve Accuracy and Speed

AI-enabled diagnostic tools reduce human error by analyzing vast datasets such as scans, lab results, and patient history. Algorithms detect anomalies invisible to the human eye and offer second-opinion reliability, accelerating diagnosis and improving treatment precision.

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2. Robotic Surgery Increases Precision and Reduces Risk

Robotic systems like da Vinci empower surgeons with sub-millimeter precision, reducing trauma and improving recovery times. These systems are essential in complex surgeries (e.g., neurosurgery) where precision impacts survival and quality of life.

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3. Personalized Treatment Through Predictive Modeling

AI enables personalized care by using genetic, physiological, and behavioral data to predict disease risk and treatment outcomes. This is particularly impactful in oncology, where tailored chemotherapy regimens can minimize side effects and maximize efficacy.

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4. Robotics Enhance Rehabilitation and Mobility

Exoskeletons and smart assistive devices restore independence for patients with spinal injuries or stroke. These robots adapt to user progress, creating personalized therapy that improves both physical and mental recovery outcomes.

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5. Telemedicine and Remote Monitoring Expand Access

AI-integrated robotic systems enable virtual consultations, remote surgeries, and real-time patient monitoring—critical in rural areas or during pandemics. Telepresence robots bring specialists to patients anywhere, mitigating geographic care disparities.

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6. Operational Efficiency and Cost Reduction

AI and robotics automate repetitive tasks—pharmacy dispensing, lab work, logistics—cutting down labor hours and errors. Hospitals using automation report fewer medication errors and lower operational costs over time.

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7. AI-Augmented Elderly and Palliative Care

Socially assistive robots like PARO offer companionship and cognitive stimulation for the elderly, reducing loneliness and enhancing emotional well-being. These robots also remind patients to take medication and alert caregivers to emergencies.

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8. AI Supports Drug Discovery and Development

AI-robotic systems screen compounds faster than humans, predicting drug toxicity and efficacy with remarkable accuracy. They optimize clinical trials by identifying the right participants and forecasting responses, shortening drug development cycles.

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9. Challenges: Ethics, Bias, and Data Privacy

AI must be trained on diverse data to avoid biased diagnoses. Clear legal frameworks are needed to define accountability, especially in surgical robots and autonomous decisions. Data privacy, especially under HIPAA/GDPR, is also critical.

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10. A Future of Integration and Augmentation—not Replacement

Rather than replacing healthcare workers, AI and robotics augment human intelligence and manual skill. The goal is a collaborative model where clinicians guide and validate machine insights while focusing on compassionate care delivery.

8. 0 Future Direction/Trend

As the autonomy of robotic systems increases, the use of robots in unstructured environments such as hospitals will expand and become more common. Increased adaptability and precision will allow medical procedures to become more personalized and truly tailored to the patient. With the constant integration of different technologies and the use of virtualization tools in the context of healthcare, the metaverse has been proposed (Wang et al., 2022). This approach to healthcare makes use of the most advanced technologies that can be applied in the context of digital health, including AI, robotics, quantum computing, IoT, and multi-robot systems. Its integration with advanced automation and decision-making tools can transform the way healthcare services are delivered (Chengoden et al., 2023; Kyrarini et al., 2021; Morgan et al., 2022).

In addition, visualization and teleoperation can enable complex medical procedures to be carried out remotely, improving access to and the quality of healthcare. However, for these technologies to be effective, it is necessary to develop new, robust, reliable, and secure solutions that can be used in cybernetic design (Morgan et al., 2022). Furthermore, these solutions must be sustainable and easy to implement (Chengoden et al., 2023). The collaboration of all interested parties, including industry, regulators, professionals, users, legislators, and governments, is essential for creating the necessary infrastructures that will allow these approaches to be implemented in our society (Morgan et al., 2022).

In healthcare, automation can improve the accuracy and efficiency of medical procedures, while multi-robot systems can collaborate in hospital environments to carry out complex tasks. Virtualization and teleoperation can enable the remote execution of surgeries and other critical procedures. Integrating these emerging technologies into hospitals will not only improve the quality of care but will also increase patient safety and reduce operating costs (Chengoden et al., 2023; Pradyumna et al., 2024).

The integration of Virtual Reality (VR) and Augmented Reality (AR) in robotics, especially in the hospital context, has been changing the paradigm of healthcare, specifically in Seetohul et al. VR and AR are two distinct but interconnected technologies that have the potential to revolutionize healthcare. VR enables access to computer-generated images, providing a simulated reality that can be indistinguishable from the physical world (Singh et al., 2023). AR enhances the real-world environment, overlaying the digital one with information from the physical environment (Singh et al., 2023).

According to Margam (2024), f uture robotic systems are anticipated to have improved capabilities that will enable them to handle a wider variety of drug formulations and compounding activities, enhancing flexibility and precision. One such system is RIVA which is developed for sterile IV compounding. An additional trend for the future is AI-driven drug management. AI algorithms are increasingly driving medicine management by utilizing patient data, drug interaction analysis, and prescription history to optimize medication regimens and reduce negative side effects, as shown with platforms like Suki.AI. These AI-driven technologies help medical professionals make wise prescription choices, eventually improving patient safety. Blockchain technology is also becoming a powerful tool for tracking down drugs. Companies like IBM and Walmart, for instance, are testing blockchain initiatives to track the beginning and progression of certain pharmaceuticals, assuring their legitimacy and compliance with quality requirements. With the help of these next developments, pharmacy automation not only promises to address present issues but also pushes for more drug management transparency, efficiency, and safety across the board in healthcare setting s.

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9 . Conclusion

Artificial Intelligence (AI) and robotics have become the twin engines propelling healthcare into an era of unprecedented precision, personalization, and predictive capabilities. This convergence offers solutions to some of the most persistent challenges in modern medicine—delayed diagnosis, rising costs, clinical errors, and inequities in healthcare access.

At the heart of AI's revolution is its ability to process and analyze enormous datasets—from imaging scans to genomic information—with speed and accuracy no human can match. AI doesn't merely detect disease—it predicts it. Machine learning models flag early signs of illnesses like cancer, cardiovascular conditions, and neurological disorders long before symptoms appear. This capability fundamentally shifts healthcare from reactive to proactive, echoing the P5 medicine model: predictive, preventive, personalized, participatory, and precise.

Simultaneously, robotics transforms the delivery of care. Surgical robots extend human dexterity, making once-impossible procedures not only possible but minimally invasive. This reduces hospital stays, post-op complications, and recovery times. Rehabilitation robotics help patients regain mobility and independence, using sensors and AI to personalize routines and monitor progress. In eldercare, socially assistive robots provide not just physical aid but also emotional companionship—addressing the loneliness epidemic among aging populations.

However, these advancements are not without their caveats. The deployment of AI and robotics raises critical ethical, legal, and social questions. Patient data, the fuel of AI systems, must be protected from breaches and misuse. Systems trained on biased data can perpetuate healthcare disparities rather than resolve them. Additionally, as AI systems begin to make autonomous decisions—such as triage prioritization or treatment recommendations—questions of accountability arise. Who is responsible if a robot makes a surgical error, or an algorithm misdiagnoses a condition?

To address these challenges, multi-stakeholder collaboration is essential. Governments, academia, technology companies, and healthcare providers must come together to establish frameworks for transparency, bias mitigation, patient consent, and data governance. At the same time, workforce reskilling and continuous education must be prioritized. AI and robotics should not replace human expertise but enhance it. Healthcare workers must be trained to understand, validate, and effectively collaborate with intelligent systems.

A critical consideration is equity. While robotic surgery is available in elite urban hospitals, rural and resource-poor settings struggle to access even basic medical care. The AI revolution must not widen this gap. Telemedicine and portable robotic solutions offer hope for democratizing access—if investments are made in digital infrastructure and public-private partnerships. In this context, Lagos State (and by extension, Nigeria) can be a case study in leapfrogging traditional limitations by adopting AI and robotics to bypass infrastructure deficits and scale up quality care delivery.

Economically, the initial costs of implementing AI-driven robotics are high—but the long-term ROI is substantial. Fewer diagnostic errors, shorter hospital stays, optimized drug development, and personalized treatments translate into savings for both providers and patients. Furthermore, the time freed up by automating repetitive tasks can be redirected towards high-value care such as patient counseling, mental health support, and chronic disease management.

Looking ahead, the frontier is expanding. We are entering an era where AI and robotics will not only assist in care but co-create it. Multi-agent robotic systems will work in sync with VR, AR, and IoT to provide fully immersive therapeutic environments. AI chatbots and virtual therapists will complement human caregivers in managing anxiety, depression, and PTSD. Blockchain will ensure secure, interoperable health records across continents. Even quantum computing may eventually fuel diagnostics beyond current comprehension.

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Sentence Breakdown

835 sentences — **399 AI** · **344 Mixed** · **92 Human**

#	SENTENCE	AI SCORE	LABEL
1	Title : Artificial intelligence (AI) revolutionizing healthcare, use of robots in treatment management, diagnostics, personalizing treatment, and improving patient care and satisfaction.	75%	AI
2	Artificial Intelligence (AI) and robotics are revolutionizing healthcare by transforming how diseases are diagnosed, managed, and treated.	82%	AI
3	This position paper explores the multifaceted applications of AI-powered robotics in diagnostics, surgical interventions, treatment management, and personalized medicine.	77%	AI
4	AI enables data-driven, real-time decision-making, while robotics ensures precision and physical execution in clinical environments.	72%	AI
5	Together, they reduce diagnostic errors, improve surgical outcomes, streamline treatment delivery, and elevate patient satisfaction.	76%	AI

399	344	92	835
AI sentences	Mixed sentences	Human sentences	Total sentences

Interpretation

Mixed content detected (58% AI score).

The document contains a mix of AI-generated and human-written content, consistent with partial AI use or AI-assisted editing.

Detection thresholds used: AI ≥72% | Mixed 42–72% | Human <42%

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