Robustness and Reliability Testing in Healthcare Using Artificial Intelligence

ABSTRACT

Testing the security, efficiency, and dependability of AI-driven healthcare systems is crucial. It is essential to perform thorough and rigorous testing to make sure the AI algorithms are capable. Our goal is to ensure that these algorithms can handle a wide range of scenarios that may occur in healthcare settings. We must observe, for instance, how well they function in the presence of changes in patient characteristics, data accuracy, and even environmental factors. Developers are able to go deeply and find any potential flaws, biases, or restrictions by thoroughly testing AI models. This enables them to enhance and maximize the algorithms' performance. Our goal is for these AI systems to be adaptable and strong, ready to overcome any challenges. Our goal is for these AI systems to be adaptable and robust, ready to overcome whatever challenges they encounter. Reliability testing is another crucial step in this process. Our goal is to guarantee that, over time, the AI predictions in actual medical contexts continue to be accurate and dependable. In the end, we rely on these systems to produce trustworthy outcomes that actually enhance patient care. Developers and healthcare institutions are not the only parties involved in this. Policymakers and regulatory bodies are also quite important. They put a lot of effort into developing standards and protocols for carrying out trustworthy and demanding AI testing in the medical field. Strict safety and efficacy standards are met by AI-driven healthcare solutions thanks to the requirements they set for testing procedures, data quality, and performance indicators. This article focuses on all the current robustness and reliability testing using AI in Healthcare.

Keywords: Artificial intelligence (AI); robustness; healthcare sector; medical devices.

1. INTRODUCTION

Artificial intelligence (AI) is a well-established concept in the healthcare business and has previously been extensively used. The incorporation of this technology is becoming more and more common in healthcare delivery, and it has the potential to greatly improve the accuracy of diagnoses, effectiveness of treatments, and overall quality of patient care [1]. AI is already employed in healthcare to develop diagnostic tools. Artificial intelligence algorithms can be trained to evaluate medical pictures, such as X-rays and CT scans, in order to detect signs of sickness or injury [2]. By implementing this approach, healthcare practitioners might potentially enhance diagnostic precision, detect issues at an earlier stage, and consequently employ less invasive or more targeted therapeutic interventions. AI is utilized in the development of personalized medicine, which is another domain of healthcare [3,4]. Artificial intelligence can aid physicians in comprehending the impact of patient genetics, environment, and lifestyle on their health by evaluating extensive amounts of medical data. With the aid of this information, healthcare providers can develop individualized treatment regimens that are more efficacious [5-7].

In recent times, health centers and hospitals have rapidly embraced new technology and advancements to create highly advanced and unmatched healthcare systems [8]. This endorses the endeavors of the FDA and the European Union (EU) to create intelligent applications for disease diagnosis and treatment that take into account ethical concerns such as privacy, transparency, safety, and accountability. Medical advancements that involve the implementation of artificial intelligence (AI) in healthcare are valuable and essential in various fields, including translational medical research, clinical practice, basic biological research, and medical image diagnostics systems [9]. Furthermore, recent advancements in artificial intelligence (AI) research in the healthcare field have utilized deep learning (DL) and machine

learning (ML) techniques to detect data patterns and elucidate intricate relationships [10]. Furthermore, the utilization of DL (Deep Learning) and ML (Machine Learning) techniques has significantly influenced the structure and development of Artificial Intelligence in the field of healthcare [11].

The healthcare sector comprises various stakeholders, such as healthcare providers, insurers, pharmaceutical companies, and regulatory authorities. These entities work together to promote and sustain the health of individuals and populations. In this field, the drive for innovation and quality is closely tied to the task of finding a balance between making services accessible and effective while maintaining the highest standards of care [12]. With the growth and ageing of populations, there is a rising need for healthcare services, which puts additional pressure on current systems. This compels the sector to undergo a necessary transformation and adjust in order to satisfy these growing needs, all while prioritizing the health and well-being of individuals [13]. In this particular situation, technology does not only serve as an addition, but rather as an essential facilitator, with AI playing a significant role in fundamentally transforming the way healthcare is provided [14,15].

AI has significant potential in treatment planning and optimization, in addition to its use in diagnostics. AI systems can utilize patient data, medical literature, and clinical guidelines to provide personalized treatment regimens that are specifically customized to particular patient characteristics and medical histories. In addition, decision support technologies driven by artificial intelligence can aid clinicians in selecting the most efficient treatments, reducing negative side effects, and maximizing treatment results [16]. Nevertheless, the extensive implementation of AI in the healthcare sector is not devoid of obstacles. Addressing ethical considerations, legislative difficulties, data privacy concerns, and the requirement for strong validation and testing frameworks is crucial due to the significant challenges they pose. Moreover, it is crucial to priorities the dependability, resilience, and comprehensibility of AI algorithms in order to cultivate confidence among clinicians, patients, and regulatory bodies [17].

2. THE EVOLUTION OF ARTIFICIAL INTELLIGENCE IN THE HEALTHCARE

The field of artificial intelligence has undergone significant advancements since the first development of the first AI program in 1951 by Christopher Strachey. During that period, artificial intelligence (AI) was in its early stages of development and was mainly focused on academic research. John McCarthy, in 1956, arranged the Dartmouth Conference, during which he introduced the phrase "Artificial Intelligence." This event signaled the commencement of the contemporary era of artificial intelligence. During the 1960s and 1970s, research in the field of artificial intelligence mostly concentrated on the development of rule-based systems and expert systems. Nevertheless, this strategy was constrained by the requirement for more computational resources and data [1].

The increased availability of extensive medical data and advancements in computer technology sparked a renewed fascination with artificial intelligence (AI) in the healthcare field during the 1980s and 1990s [18,19]. This, in turn, led to the development of innovative AI approaches that were more flexible and powerful compared to expert systems. Examples of such techniques include neural networks and decision trees. These ideas have been used to produce various applications, such as decision support systems and diagnostic tools [20,21]. One notable accomplishment of AI in healthcare was the development of an expert system for identifying breast cancer. The IDC-P approach, incorporating data from mammograms and other medical examinations, effectively detected breast cancer. The utilization of artificial intelligence (AI) in healthcare has experienced a substantial rise in recent years, thanks to advancements in AI techniques such as deep learning and the availability of extensive data [22].

The introduction of machine learning algorithms in the 1980s and 1990s marked the beginning of a new era of artificial intelligence in healthcare. This was made possible by advancements in computing technology and the adoption of data-driven methodologies. Researchers utilized advanced techniques such as neural networks, decision trees, and genetic algorithms to analyze medical data, discover patterns, and make predictions [15]. The AI models exhibited encouraging outcomes in domains such as the interpretation of medical images, the stratification of illness risks, and the identification of new drugs, establishing the groundwork for forthcoming applications.

During the transition to the 21st century, there was a significant increase in attention and financial support for healthcare AI. This was

motivated by the combination of large amounts of data, cloud computing, and advanced deep learning methods [23]. Advancements in image identification, natural language processing, and reinforcement learning have allowed AI systems to exceed human capabilities in tasks such as

Table 1. Evolutionary eras of AI in healthcare

Era	Characteristics
Pre-2010	Basic AI applications, such as decision support systems and medical imaging analysis, emerge.
2010-2015	Rapid growth in AI adoption due to advances in machine learning algorithms and increased computing power. AI applications expand to areas like personalized medicine, drug discovery, and patient monitoring.
2015-2020	Deep learning revolutionizes medical image analysis, leading to improved diagnostics and treatment planning. AI-driven virtual health assistants and chatbots gain popularity for patient engagement and triage. Ethical concerns regarding data privacy and bias arise.
2020-2025	AI integrates with electronic health records (EHR) systems for predictive analytics, clinical decision support, and workflow optimization. AI-powered wearable devices and remote monitoring solutions enable continuous patient care outside traditional healthcare settings.
Beyond 2025	AI becomes ubiquitous in healthcare, facilitating precision medicine through genomic analysis, enabling autonomous robotic surgeries, and revolutionizing drug development pipelines. Ethical and regulatory frameworks evolve to address AI's complex role in healthcare delivery.

identifying diseases from medical photos, extracting valuable information from unstructured clinical notes, and optimizing treatment plans. Furthermore, the widespread use of electronic health records (EHRs) and efforts to improve the exchange of health data have resulted in abundant data sources for training and verifying AI models. This has expedited the integration of AI technology into real-world healthcare environments [13].

AI in healthcare has reached a stage of maturity and widespread acceptance in recent years, with an increasing focus on robustness, reliability, and clinical validation. AI-driven diagnostic tools, such as computer-aided detection (CAD) systems and algorithmic triage systems, are becoming more and more incorporated into radiology departments, pathology labs, and primary care clinics. These tools enhance the capacities of healthcare workers and enhance diagnostic precision. AI-powered predictive analytics and risk stratification models are being used to identify patients at high risk, allocate resources efficiently, and personalize treatment regimens. This leads to a more effective and cost-efficient delivery of healthcare [24].

In 2007, IBM developed an open-domain question-answering system called Watson. Watson successfully competed against human competitors and emerged as the winner of the television game show Jeopardy! in 2011. Unlike conventional systems that relied on forward reasoning, backward reasoning, or manually created if-then rules, the technology known as DeepQA employed natural language processing and diverse searches to examine unstructured content and produce likely answers. This system was readily accessible, simpler to upkeep, and more economical [25].

DL represented a significant breakthrough in AIM. Unlike ML, which relies on a fixed number of characteristics and necessitates human intervention, DL may autonomously learn to categorize data. Despite being initially explored in the 1950s, the utilization of DL in medicine was constrained due to the issue of "overfitting." Overfitting arises when machine learning algorithms excessively specialized on a particular dataset, leading to a diminished ability to effectively interpret novel datasets. This phenomenon can be attributed to inadequate computational resources and a dearth of training data [26]. In the 2000s, the restrictions were successfully overcome by the availability of larger datasets and greatly enhanced processing capacity. A convolutional neural network (CNN) is a deep learning technique used for image processing that emulates the linked neuron behavior of the human brain. A Convolutional Neural Network (CNN) consists of multiple layers that analyze an input image in order to identify patterns and generate specialized filters. The ultimate result is generated through the amalgamation of all characteristics by the completely connected layers [26,27].

There are currently multiple CNN algorithms that can be used, such as Le-NET, AlexNet, VGG, GoogLeNet, and ResNet[28].

3. RELIABILITY TESTING

The medical sector is one of the most potential industries for the adoption of artificial intelligence (AI) technologies. In recent years, numerous effective applications utilizing clinical decision support systems (CDSSs) have been developed. As a result, AI applications in the medical industry have progressively transformed the field. A collaboration between doctors and computer scientists is underway to enhance medical services by implementing automated technologies that can enhance the precision of disease diagnosis and facilitate the prescription of appropriate treatments [29]. AI applications in the medical industry have specifically aided physicians by assisting in the development of diagnostic assumptions, offering explanations for clinical reasoning, and facilitating the selection of suitable treatments. These applications have been highly successful in recognizing and diagnosing health hazards in clinical practices across numerous institutions globally [30].

In addition, the U.S. Food and Drug Administration (FDA) has granted approval for the use of artificial intelligence (AI) technologies into the medical industry with the aim of enhancing healthcare services and reducing health hazards [31]. In recent times, health centers and hospitals have rapidly implemented new technology and advancements to create highly advanced entities that are unmatched in the field of healthcare. This endorses the FDA and European Union's (EU) endeavours to create intelligent applications for disease diagnosis and treatment that take into account ethical concerns such as privacy, transparency, safety, and accountability [8].

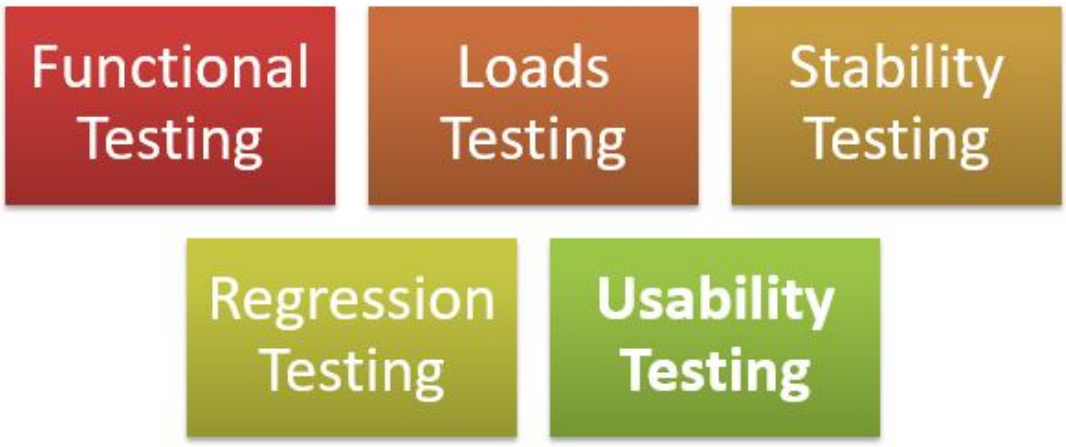

Fig.1. Types of reliability testing

An essential component of reliability testing involves assessing the reliability and uniformity of AI predictions across diverse datasets and testing circumstances. Artificial intelligence algorithms that are trained on datasets that are diverse may demonstrate different degrees of performance, which raises questions about their capacity to be applied effectively and reliably in real-world situations. dependability testing entails the validation of AI models using separate datasets, evaluating their consistent performance across time, and finding any factors of variability or bias that could affect their dependability [32].

Another crucial factor to consider in reliability testing is evaluating the influence of uncertainty and variability in medical data on AI predictions. Healthcare data, including medical pictures, laboratory results, and patient records, possess intrinsic noise and are susceptible to uncertainty caused by factors such as imaging artefacts, measurement mistakes, and subjective interpretations. Reliability testing entails assessing the robustness of AI algorithms in the presence of uncertainties, guaranteeing their capacity to sustain performance and accuracy when confronted with real-world difficulties [33]. Reliability testing involves assessing the resilience of AI algorithms against adversarial

assaults and unforeseen inputs that could potentially undermine their performance or integrity. Adversarial assaults entail intentionally changing input data to fool or misguide AI algorithms, resulting in inaccurate predictions or weaknesses in AI systems. Reliability testing seeks to detect and address potential hazards by evaluating the strength of AI models against adversarial examples and subjecting them to stress tests to measure their capacity to withstand potential attacks [34].

Moreover, reliability testing in healthcare AI entails evaluating the clinical soundness and usefulness of AI predictions in actual clinical environments. While AI algorithms may exhibit remarkable performance in controlled research settings, they may be ineffective in providing valuable insights or practical recommendations when implemented in clinical practice. Reliability testing include the performance of forward-looking evaluations, user studies, and clinical validation studies to evaluate the clinical influence and efficacy of AI-powered healthcare solutions. AI algorithms have been extensively employed in the healthcare sector since 2017, demonstrating their capacity to evaluate and comprehend vast quantities of medical data that may be challenging or impractical for humans to comprehend [29].

An essential aspect of healthcare artificial intelligence (AI) is the acquisition of informed consent from patients. This process entails collaborative decision-making between doctors and patients, ultimately granting the patient the authority to make the final decision. In order to implement healthcare AI, it is crucial to ensure that patients are thoroughly educated on its functionalities and operational mechanisms. To fulfil this goal, research has concentrated on creating Explainable Artificial Intelligence (XAI) systems for healthcare professionals that can augment their cognitive processes and improve their decision-making abilities. In future studies, it is recommended to incorporate a new phase (section) of Explainable Artificial Intelligence (XAI) to accurately assess the levels of relevance of features in the trained model. This article shows a comparison between two models that were trained to detect shoulder problems. Both models accurately anticipated the image based on their levels of confidence [35].

4. ISSUES IN ENSURING RESILIENCE AND DEPENDABILITY TESTING

The current resurgence in AI confronts the crucial obstacle of reliability. Many policymakers and researchers have been focused on addressing the problem of trust, transparency, and ethics in AI-based healthcare applications [36]. The credibility of AI applications in the fields of biomedicine and healthcare plays a crucial role in determining the acceptance and implementation of AI technology. The utilization of AI in the healthcare sector would enhance the delivery of high-quality medical services and patient care, leading to an increase in trust from practitioners and policymakers. On the other hand, the absence of reliability in AI applications poses a significant obstacle to using advanced technologies [37]. The rise in legal and ethical concerns poses numerous obstacles for these types of applications, as clinical and medical judgments have a direct impact on people's welfare. Moreover, the delicate reliability of AI worsens decision-making issues for patients and clinicians and diminishes responsibility for mistakes. Hence, the precise delineation of reliable AI applications remains ambiguous [38]. However, the literature highlights three fundamental principles for attaining reliable AI: legitimacy, morality, and robustness. Specifically, the legal aspect pertains to compliance with regulations and laws, the ethical aspect signifies a dedication to values and moral standards, and the robustness aspect relates to concerns for safety and security. Moreover, the implementation of fundamental principles of reliable AI in practical terms is an ongoing and indefinite difficulty [39].

Insufficient transparency is recognized as a significant obstacle to implementation [38,40]. Given that doctors are entrusted with providing optimal treatment to every patient, it is imperative that they have full confidence in the reliability and trustworthiness of AI systems, including AI models and all other components of their implementation. The health care field presents distinctive ethical, legal, and regulatory obstacles due to the fact that choices made can directly and immediately affect the health and even survival of individuals [41]. Frequently cited issues are around the possibility of algorithmic bias and the absence of model robustness or generalizability. Additional issues encompass the AI system's incapacity to elucidate the process by which decisions are made to medical professionals and patients, challenges in attributing responsibility for errors, and susceptibility to malevolent assaults [42].

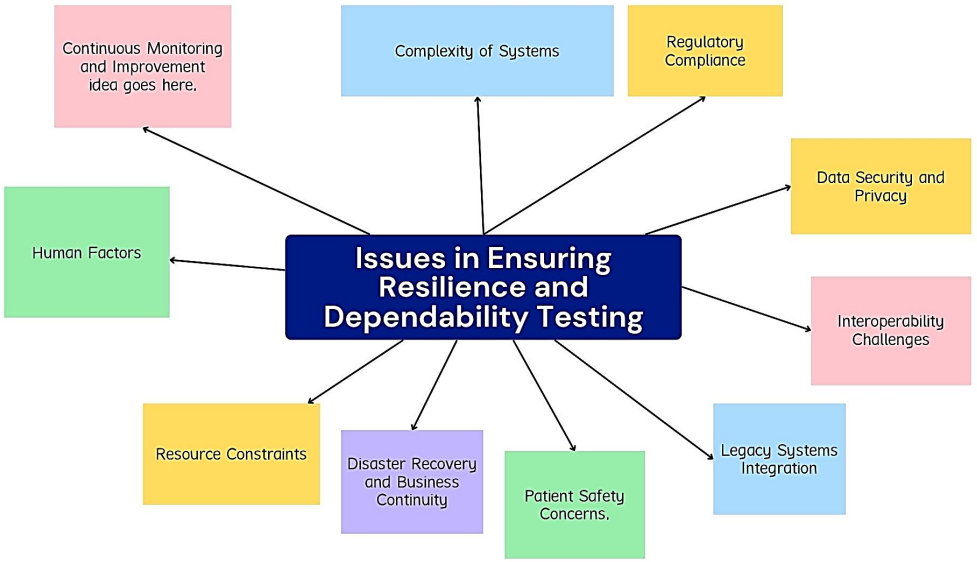

Fig.2.Some key issues

AI models, which consist of complex algorithms and interrelated components, present challenges in understanding their internal mechanisms, particularly when functioning as opaque entities. The reliability of AI systems is closely tied to the calibre and variety of the data they acquire knowledge from. However, guaranteeing the integrity and representativeness of data can be challenging, as biases, mistakes, and inadequacies have the potential to distort results. Furthermore, the susceptibility of AI systems to adversarial assaults highlights the need for rigorous testing to ensure their resilience against deliberately created disturbances that are intended to cause inaccurate outputs [43].

During real-world implementation, AI systems face ever-changing and uncertain conditions, necessitating thorough testing in many situations and challenging scenarios to guarantee reliable performance. Moreover, the testing procedure requires meticulous scrutiny of ethical factors, including fairness, transparency, and accountability. To tackle these ethical and societal repercussions, it is necessary to incorporate ethical frameworks into testing techniques in order to foster responsible AI development. Adherence to strict standards is crucial, especially in sectors such as healthcare and finance, where regulatory compliance adds complexity to the situation. Therefore, testing protocols must include regulatory mandates to ensure compliance with legal and ethical standards [44].

The administration of AI systems throughout their lifecycle introduces an additional level of intricacy, since these systems undergo changes over time, requiring ongoing testing, monitoring, and maintenance to ensure their reliability. Continuous testing is essential for identifying and resolving issues that may occur as a result of updates, upgrades, or modifications in underlying technology [45]. The collaboration of interdisciplinary experts is essential, as it combines the expertise of AI specialists, software engineers, ethicists, and professionals with domain-specific knowledge to navigate the complex terrain of AI testing. By implementing rigorous processes and utilizing sophisticated testing techniques, such as adversarial testing and fuzz testing, organizations can enhance their resilience and dependability by identifying vulnerabilities and reducing risks[46].

To tackle the issues surrounding the trustworthiness of AI, many methods, tactics, and rules have been put in place to improve the dependability and ethical standards of AI systems. An essential approach entails the creation of ethical principles and frameworks for artificial intelligence. Regulatory bodies such as the European Union have introduced guidelines like the Ethics Guidelines for Trustworthy AI, which delineate concepts such as openness, justice, and responsibility in artificial intelligence systems [47]. Similarly, the IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems offers extensive principles with the goal of ensuring ethical, transparent, and accountable development of artificial intelligence. In the

industry, technology businesses and artificial intelligence (AI) developers are progressively implementing internal standards and processes to enhance the dependability of AI [48]. These encompass stringent testing standards, measures to mitigate prejudice, and the establishment of ethics review committees. There is a growing trend in the industry towards implementing Explainable AI (XAI) techniques, which seek to enhance the transparency and comprehensibility of AI decision-making processes for humans [49].

5. TESTING METHODOLOGIES

Testing approaches are crucial in guaranteeing the dependability, resilience, and effectiveness of AI systems in various applications. These methodologies consist of a variety of strategies and approaches specifically designed to suit the distinct qualities and needs of AI systems. An essential component of AI testing involves validating models against training data to evaluate their accuracy and ability to generalize. This procedure entails dividing the accessible data into training, validation, and test sets, facilitating meticulous assessment of model performance and detection of potential problems such as over fitting or underfitting.AI testing approaches commonly incorporate many forms of functional testing to ensure that the system operates as anticipated in various scenarios, in addition to data validation [50].

This may entail conducting unit testing on specific components or modules inside the AI system, performing integration testing to assess the interactions between components, and conducting system testing to evaluate the overall functioning and performance of the system as a whole. These testing procedures aid in the detection of defects, faults, or inconsistencies that may occur during the development or deployment of AI systems [51]. Another crucial part of AI testing involves assuring the durability and resistance of models against adversarial attacks or unforeseen inputs. Adversarial testing is the deliberate act of altering input data to assess the model's response and its ability to resist manipulation or deception. Conducting this type of testing is especially crucial for AI systems used in security-sensitive applications like self-driving cars, as the repercussions of a malfunction might be serious [52].

Moreover, AI testing methodologies frequently include approaches to evaluate the impartiality, clarity, and responsibility of models, particularly in situations where ethical concerns are of utmost importance. Fairness testing entails assessing if the AI system demonstrates biases or discrimination towards specific groups or individuals, while transparency testing centers on comprehending how the model reaches its judgments and whether it can be elucidated or interpreted by human users. Accountability testing aims to develop methods for assigning accountability in situations where AI systems cause harm or do not achieve anticipated performance requirements [53].

Recently, there has been an increasing interest in using advanced testing techniques like fuzz testing and generative adversarial testing to enhance standard methodologies. Fuzz testing entails supplying the AI system with a substantial quantity of arbitrary or erroneous inputs in order to detect weaknesses or exceptional scenarios that may not be detected by traditional testing methods. Generative adversarial testing, derived from the idea of adversarial training in machine learning, involves the competition between two AI systems. One system generates adversarial examples, while the other system tries to identify and detect these examples. The purpose of this process is to enhance the resilience and security of AI models [50].

Table 2. AI testing methodologies in the context of dependability, resilience, and effectiveness of healthcare systems

Methodology	Description
Unit Testing	Testing individual units or components of the AI system to ensure they function correctly and meet the specified requirements. This can involve testing algorithms, data processing modules, and other components in isolation.
Integration Testing	Verifying that different modules or components of the AI system work together as expected. This involves testing the interactions between various parts of the system to ensure they integrate seamlessly and perform as intended.
System Testing	Evaluating the entire AI system as a whole to validate that it meets the defined requirements and functions correctly in its intended environment. This involves testing the system's overall behavior, performance, and functionality.

Regression Testing	Testing the AI system after modifications or updates to ensure that existing functionalities have not been adversely affected. This helps in maintaining the dependability and effectiveness of the system over time.
Stress Testing	Assessing the AI system's robustness and resilience by subjecting it to conditions beyond normal operational limits. This helps identify potential weaknesses or vulnerabilities in the system under high-stress scenarios.
Performance Testing	Measuring and evaluating the AI system's performance metrics such as speed, throughput, and resource utilization under various conditions. This ensures that the system can handle the workload effectively and efficiently.
Security Testing	Identifying and addressing vulnerabilities in the AI system that could be exploited to compromise data integrity, confidentiality, or system availability. This is crucial for maintaining the security and trustworthiness of healthcare systems.
Usability Testing	Assessing the ease of use and user experience of the AI system from the perspective of healthcare professionals, patients, or other stakeholders. This helps ensure that the system is intuitive, efficient, and user-friendly.
Ethical Testing	Evaluating the ethical implications and potential biases of the AI system, particularly concerning sensitive healthcare data and decision-making processes. This involves ensuring fairness, transparency, and accountability in system behaviors.

In addition, the development of automated testing tools and frameworks designed expressly for AI systems has made it easier to implement more organized and scalable testing methods. These tools frequently incorporate functionalities like model validation, test case development, and performance monitoring, which allow developers to optimize the testing process and uncover faults with more efficiency [54].

Although there have been significant improvements in testing procedures for AI, there are still some obstacles to overcome, especially when it comes to guaranteeing the consistency and dependability of results across various environments and datasets. The absence of standardized benchmarks and evaluation criteria presents challenges in objectively assessing the performance of various models or methodologies [55]. Furthermore, the swift rate of advancement in AI research and development requires ongoing adjustment and improvement of testing techniques to stay up to date with changing technology and applications. Testing strategies for AI systems involve a wide range of techniques and approaches specifically designed to tackle the distinct issues presented by these intricate and ever-changing systems [56]. A complete testing framework is crucial to verify the dependability, robustness, and ethical integrity of AI systems in different applications. This framework includes data validation, functional testing, robustness evaluation, and fairness assessment. Through the utilization of sophisticated testing methodologies, automated software, and cross-disciplinary cooperation, stakeholders may improve the efficacy and efficiency of AI testing and promote the creation of AI systems that are more dependable and trustworthy [57].

6. CASE STUDIES AND EXAMPLES

AI-driven innovations strive to replicate human cognitive abilities, and the capacity of AI-powered robots to comprehend and manage vast information has progressed swiftly. An advantage of implementing AI in healthcare during the era of big data is the ability to algorithmically uncover intricate patterns and relationships within the data, eliminating the need to recruit more healthcare specialists for data analysis[58]. AI advancements have diverse healthcare applications, including the ability to forecast death rates following heart surgery, the development of intelligent artificial prostheses, and the fast diagnosis of skin cancer, perhaps surpassing the capabilities of dermatologists. Nevertheless, the healthcare industry lags behind other industries in terms of digitalization and the rate at which it adopts artificial intelligence (AI) [59].

The use of AI in nutrition offers exceptional potential for growth and numerous opportunities in this discipline. Computational techniques are increasingly utilized in healthcare, specifically in nutrition research, to handle the vast and intricate amount of data gathered in this discipline. The progress and enhancement of nutritional assessment tools have been facilitated by AI-based approaches, leading to enhanced forecasting of health consequences based on dietary exposures [60]. The integration of AI technology began to enhance the domains of food science and nutrition research in the latter

part of the 2010s. There have been numerous technological advancements in the field of food science and nutrition. These include personalized nutrition, automated control of diets and recipe evaluation, testing the sustainability of food, precision medicine for improved disease diagnosis, and the development of decision-support tools for parenteral nutrition. Additionally, there have been advancements in remote nutrition evaluation using telehealth, wearable technologies, and mobile applications specifically focused [61].

Artificial Intelligence (AI) has become a transformative power in the healthcare field, revolutionizing the methods used by medical practitioners to diagnose, treat, and manage diseases. AI has the potential to improve patient outcomes, streamline workflows, and increase efficiency in healthcare by analyzing large volumes of data, identifying trends, and making predictions [62].

- **Advancements in diagnostics** have been greatly enhanced by the implementation of AI in healthcare, particularly in the field of medical diagnostics. Artificial intelligence algorithms, driven by machine learning and deep learning approaches, have shown exceptional precision in analyzing medical pictures like X-rays, MRIs, and CT scans. AI rapidly detects irregularities and highlights possible areas of concern, aiding radiologists and clinicians in promptly and accurately diagnosing patients. This helps speed up the start of treatment and enhances the outlook for patients [63].

Furthermore, AI-powered diagnostic tools are not restricted solely to imaging; they also encompass fields like pathology and genomes. AI algorithms in pathology can efficiently analyze tissue samples, assisting pathologists in identifying malignant cells and other abnormalities with exceptional accuracy. AI algorithms are crucial in genomics for analyzing genetic data and enabling personalized medicine. They help identify people' vulnerability to specific diseases and customize treatment strategies appropriately [64].

- **Predictive analytics and preventive care** go beyond diagnosis by harnessing the power of AI. This technology equips healthcare providers with the ability to foresee and intervene proactively in order to prevent unfavorable events. AI algorithms can detect trends in patient data obtained from electronic health records (EHRs), wearable devices, and other sources. These patterns can indicate potential health hazards, such as worsening vital signs or failure to follow medication instructions. Equipped with this foresight, medical professionals can apply precautionary actions, provide specific therapies, and include patients in proactive healthcare administration, thereby preventing problems and decreasing hospitalizations [65].

- **Precision medicine**, which involves customized therapies based on individuals' specific genetic composition, is significantly aided by artificial intelligence (AI) technologies. AI can utilize advanced data analysis techniques to interpret intricate genomic datasets and detect genetic markers linked to certain diseases or treatment responses. This allows healthcare professionals to prescribe pharmaceuticals that are more probable to be efficacious and less prone to inducing adverse effects, so maximizing therapeutic results and minimizing healthcare expenses [66].

- **Virtual health assistants and telemedicine** platforms are becoming essential tools in the digitized healthcare industry, as they enhance patient access and engagement through the use of AI technology. These highly intelligent virtual agents, which have advanced natural language processing skills, are able to engage with patients in real-time[67]. They can respond to inquiries, schedule appointments, and offer personalized health advice. Furthermore, telemedicine platforms utilize artificial intelligence algorithms to facilitate remote consultations, allowing patients to receive prompt medical guidance and treatment without the necessity of in-person visits to healthcare facilities. This effectively broadens the availability of healthcare, especially in areas that lack adequate access to medical services [64].

- **Operational efficiency and cost reduction:** AI has significant potential to optimize healthcare operations and achieve cost reductions, in addition to its clinical uses. Artificial intelligence-powered predictive modeling can accurately predict patient demand, allowing healthcare services to efficiently distribute resources

and optimize staffing levels to align with patient numbers. Moreover, automation solutions that utilize artificial intelligence efficiently simplify administrative activities, such as billing and coding, hence decreasing the amount of paperwork and minimizing mistakes. AI improves operational efficiency and decreases administrative costs, allowing healthcare organizations to commit more resources to direct patient care and control expenses [68].

- **Ethical and regulatory considerations** arise from the extensive implementation of AI in healthcare, necessitating the need to tackle associated difficulties. The need of developing strong governance frameworks and regulatory standards to protect patient rights and ensure fairness in algorithms is highlighted by concerns about data privacy, algorithm bias, and accountability. Furthermore, as artificial intelligence (AI) progresses, it is crucial to implement continuous education and training program to provide healthcare workers with the essential expertise to utilize AI technology in a responsible and ethical manner [64].

6.1 Ethical and Legal Implications

The incorporation of Artificial Intelligence (AI) in healthcare has initiated a new epoch of ingenuity, pledging to transform patient care, diagnosis, and treatment. Nevertheless, with the growing complexity and prevalence of AI systems in medical environments, a multitude of ethical and legal concerns arise, necessitating cautious handling. It is crucial to consider the ethical and legal aspects of AI in order to maintain patient safety, privacy, and autonomy, as well as to build trust in AI-based healthcare solutions [69].

- **Patient privacy and data security** are significant ethical considerations associated with the use of AI in healthcare. AI algorithms depend on extensive quantities of sensitive patient data, such as medical records, diagnostic pictures, and genomic information, in order to produce valuable insights and make well-informed recommendations [70]. Therefore, it is of utmost importance to priorities the maintenance of patient data confidentiality, integrity, and availability in order to prevent unauthorized access, data breaches, and privacy violations. Healthcare organizations are required to establish strong data protection protocols, including encryption, access controls, and secure data storage, in order to protect patient information and adhere to regulatory mandates, such as the Health Insurance Portability and Accountability Act (HIPAA) in the United States [71].

Algorithmic bias and fairness pose an ethical dilemma in AI-driven healthcare. There is a possibility that AI systems may display discriminating behavior or generate erroneous results, especially for disadvantaged populations. The presence of biases in the training data, specifically related to race or gender, can contribute to the continuation of inequalities in the provision of healthcare and worsen the already existing discrepancies in the availability of high-quality care [72]. To mitigate algorithmic bias, it is essential to ensure transparency and accountability at every stage of the AI development process, encompassing data collection, model training, and algorithm deployment. Healthcare providers and AI developers should establish rigorous validation procedures, perform frequent audits, and address biases in order to guarantee fair and impartial AI-based decision-making [73].

Considering the consent and the importance of patient autonomy: Preserving patient autonomy and informed consent becomes of utmost importance as AI technologies are more and more integrated into healthcare practice. Patients are entitled to comprehend the impact of AI algorithms on their healthcare choices, encompassing diagnostic, treatment suggestions, and risk evaluations. Healthcare providers should engage in transparent communication with patients regarding the utilization of AI in their treatment, including addressing its limitations, uncertainties, and potential consequences. Furthermore, it is crucial to provide patients with the option to decline AI-driven therapies and maintain authority over their healthcare decisions. This approach preserves their autonomy and guarantees the acknowledgment of their specific preferences and beliefs [74].

Medical Ethics and Responsibility: The integration of AI in healthcare gives rise to intricate inquiries concerning medical liability and accountability when bad results or blunders are ascribed to AI systems. Establishing accountability for AI-related mishaps, such as incorrect diagnoses or errors in treatment, presents substantial legal complexities, as

conventional medical malpractice frameworks may not sufficiently account for the distinct attributes of AI-powered healthcare [56]. Collaboration among healthcare providers, AI developers, and regulatory agencies is necessary to set precise norms and criteria for evaluating liability, assigning duty, and guaranteeing accountability in AI-facilitated healthcare. In addition, comprehensive documentation, openness, and post-market surveillance measures are crucial for monitoring the performance of AI, detecting potential dangers, and effectively managing liability problems [67].

Adherence to regulations and standards: To effectively navigate the intricate legal framework that governs AI in healthcare, one must possess a thorough comprehension of the relevant laws, regulations, and industry standards. Healthcare organizations are obligated to comply with regulatory mandates, including the laws set forth by the Food and Drug Administration (FDA) for medical devices and the General Data Protection Regulation (GDPR) established by the European Union for data privacy [73]. Adhering to ethical criteria, such as the American Medical Association's Code of Medical Ethics and the Hippocratic Oath, is of equal significance in maintaining professional integrity and ethical values in AI-driven healthcare. Furthermore, it is crucial to cultivate cooperation among politicians, healthcare stakeholders, and technology specialists in order to establish unified norms and standards that encourage innovation while protecting the rights and well-being of patients [75].

The ethical and legal ramifications of AI in healthcare present complex difficulties that necessitate thoughtful deliberation and proactive actions to resolve. To effectively address the ethical and legal challenges of AI-driven healthcare, it is necessary to collaborate, be transparent, and have ethical foresight. This includes protecting patient privacy and autonomy, reducing algorithmic bias, and assuring accountability. To fully leverage the revolutionary capabilities of AI in healthcare, it is crucial for healthcare stakeholders to abide by ethical standards, comply with legal obligations, and promote a culture of responsible innovation. This approach ensures the protection of patient well-being and instills confidence in AI-powered healthcare solutions [76].

7. FUTURE PERSPECTIVES

The future of AI is filled with promising prospects in diverse fields, and its potential influence on society, business, and technology is significant. As we explore this terrain, there are several crucial opportunities and recommendations that can influence the future course of AI.

Through continuous research and development, AI technologies will further improve, leading to significant advancements in fields like healthcare, education, transportation, and more. AI-powered solutions will transform industries, optimize processes, and improve efficiency, ranging from personalized medicine and predictive maintenance to autonomous vehicles and smart cities [77]. Ensuring ethical and responsible AI development is of utmost importance as AI becomes more interwoven into daily life. This encompasses the task of identifying and rectifying biases present in algorithms, advocating for openness and responsibility, and ensuring the protection of privacy and data security. To avoid possible hazards and build confidence in AI systems, it is crucial to priorities ethical issues and implement strong governance frameworks [78].The collaboration between humans and AI has great promise, as AI technologies may enhance human expertise, automate repetitive jobs, and enable workers to concentrate on more innovative and strategic pursuits. By cultivating a harmonious collaboration between humans and AI, we can open novel prospects for innovation and productivity [52]. Investment in education and workforce development is needed to fully leverage the capabilities of AI. This include the provision of training program, initiatives to enhance existing talents, and opportunities to acquire new skills, all aimed at equipping individuals with the necessary abilities to succeed in an economy that is heavily influenced by artificial intelligence. Furthermore, it is crucial to advocate for diversity and inclusivity in the recruitment process for AI professionals in order to guarantee a wide array of viewpoints and specialized knowledge [79].

Establishing strong regulatory and policy frameworks is crucial in order to effectively govern the responsible implementation and use of AI technologies. This encompasses the creation of guidelines for ethical practices in artificial intelligence, the management of data, the responsibility for algorithms, and the frameworks for legal liability. Through engaging with stakeholders from various sectors, policymakers have the ability to establish a conducive atmosphere that promotes innovation while safeguarding social interests [80]. Artificial

Intelligence (AI) is an international undertaking that goes beyond national boundaries and academic fields. In order to tackle intricate problems and fully harness the capabilities of AI, it is crucial to promote international collaboration and collaborations. Through the dissemination of optimal methodologies, the exchange of information, and the consolidation of resources, the international community may expedite advancements and guarantee fair and impartial availability of artificial intelligence advantages on a global scale [55].

The future of AI holds great promise and potential. However, achieving this vision necessitates proactive initiatives and deliberate investments. By progressing AI applications, advocating for ethical development, cultivating collaboration between humans and AI, investing in education and workforce development, creating regulatory frameworks, and fostering global cooperation, we can lay the foundation for a future in which AI acts as a catalyst for positive change, fueling innovation, prosperity, and societal well-being [81-84].

8. CONCLUSION

AI integration in healthcare offers unparalleled opportunity to enhance patient care, streamline operations, and boost clinical outcomes in the ever-changing healthcare industry. Nevertheless, the effective implementation of AI in healthcare relies on rigorous and dependable testing to guarantee the safety, effectiveness, and credibility of AI-powered solutions. Robustness testing is crucial for evaluating the durability and adaptability of AI algorithms under various settings, including variations in patient demographics, data quality, and environmental factors. Developers can enhance the performance of AI models by putting them to rigorous testing across many scenarios, which allows them to find vulnerabilities, biases, and limitations. This process enables developers to tweak algorithms and increase overall performance. Reliability testing is essential for verifying the consistency and accuracy of AI predictions over time, guaranteeing that these systems provide dependable outcomes in real-world clinical environments. By consistently monitoring and evaluating, healthcare organizations may detect emerging problems, respond to feedback, and systematically enhance AI algorithms to more effectively fulfill the requirements of patients and providers. In addition, regulatory agencies and legislators have a vital role in setting criteria and rules for rigorous and dependable testing of AI in the healthcare sector. Regulatory authorities may verify that AI-driven healthcare solutions fulfill strict safety and effectiveness criteria by establishing precise requirements for testing methodologies, data quality, and performance indicators. Furthermore, it is crucial to have clear and open disclosure of testing outcomes and strict adherence to ethical guidelines in order to establish confidence and ensure responsibility in AI-powered healthcare. In order to ensure the responsible implementation of AI technologies in healthcare, it is imperative for industry stakeholders, regulatory organizations, and academia to work together collaboratively. This collaboration is essential for the development of standardized methods for verifying the robustness and dependability of these technologies.

Consent

As per international standards or university standards, patient(s) written consent has been collected and preserved by the author(s).

Ethical Approval:

As per international standards or university standards written ethical approval has been collected and preserved by the author(s).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Please write this section

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1.
2.
3.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Davenport T, Kalakota R. The potential for artificial intelligence in healthcare. Future Healthcare Journal. 2019;6(2):94.
2. Soomro TA, et al. Artificial intelligence (AI) for medical imaging to combat coronavirus disease (COVID-19): A detailed review with direction for future research. Artificial Intelligence Review, 2022: p. 1-31.
3. Kumar Y, et al. Artificial intelligence in disease diagnosis: A systematic literature review, synthesizing framework and future research agenda. Journal of Ambient Intelligence and Humanized Computing. 2023;14(7):8459-8486.
4. Oren O, Gersh BJ, Bhatt DL. Artificial intelligence in medical imaging: Switching from radiographic pathological data to clinically meaningful endpoints. The Lancet Digital Health. 2020;2(9):e486-e488.
5. Bajwa J, et al. Artificial intelligence in healthcare: Transforming the practice of medicine. Future Healthcare Journal. 2021;8(2):e188.
6. Johnson KB, et al. Precision medicine, AI, and the future of personalized health care. Clinical and Translational Science. 2021;14(1):86-93.
7. Ness S. Integrating Sociopolitical, and Cultural Dimensions into the Donabedian Framework for Comparative Legal and Healthcare Policy Analysis; 2024.
8. Amann J, et al. Explainability for artificial intelligence in healthcare: A multidisciplinary perspective. BMC Medical Informatics and Decision Making. 2020; 20:1-9.
9. Check Hayden E. The automated lab. Nature. 2014;516(7529):131-132.
10. Santamaría J, Cordón O, Damas S. A comparative study of state-of-the-art evolutionary image registration methods for 3D modeling. Computer Vision and Image Understanding. 2011;115(9):1340-1354.
11. Deo RC. Machine learning in medicine. Circulation. 2015;132(20):1920-1930.
12. Jacovi A, et al. Formalizing trust in artificial intelligence: Prerequisites, causes and goals of human trust in AI, in Proceedings of the 2021 ACM conference on fairness, accountability, and transparency; 2021.
13. Matheny M, et al. Artificial intelligence in health care: The hope, the hype, the promise, the peril. Washington, DC: National Academy of Medicine; 2019.
14. Glikson E, Woolley AW. Human trust in artificial intelligence: Review of empirical research. Acad Manag Ann. 2020;14.
15. Tsamardinos I, et al. Algorithms for large scale Markov blanket discovery. FLAIRS Conference; 2003.
16. Bajwa J, et al. Artificial intelligence in healthcare: Transforming the practice of medicine. Future Healthc J. 2021;8.
17. Epstein Z, et al. Art and the science of generative AI. Science. 2023;380.
18. Kulikowski CA. Beginnings of artificial intelligence in medicine (AIM): Computational artifice assisting scientific inquiry and clinical art–with reflections on present aim challenges. Yearbook of Medical Informatics. 2019;28(01):249-256.
19. Sarker IH. Deep learning: A comprehensive overview on techniques, taxonomy, applications and research directions. SN Computer Science. 2021; 2(6):420.
20. Baxi V, et al. Digital pathology and artificial intelligence in translational medicine and clinical practice. Modern Pathology. 2022; 35(1):23-32.
21. Jiang F, et al. Artificial intelligence in healthcare: Past, present and future. Stroke and Vascular Neurology. 2017;2(4).
22. Roy SD, et al. Computer aided breast cancer detection using ensembling of texture and statistical image features. Sensors. 2021;21(11):3628.
23. Vamathevan J, et al. Applications of machine learning in drug discovery and development. Nat Rev Drug Discov. 2019; 18.
24. Kline A, et al. Multimodal machine learning in precision health: A scoping review. NPJ Digit Med. 2022;5.
25. Ferrucci D, et al. Watson: Beyond jeopardy! Artificial Intelligence. 2013;199: 93-105.
26. Yang YJ, Bang CS. Application of artificial intelligence in gastroenterology. World Journal of Gastroenterology. 2019;25(14): 1666.
27. Hoogenboom SA, Bagci U, Wallace MB. Artificial intelligence in gastroenterology. The current state of play and the potential. How will it affect our practice and when? Techniques and Innovations in Gastrointestinal Endoscopy. 2020;22(2): 42-47.

28. Vinsard DG, et al. Quality assurance of computer-aided detection and diagnosis in colonoscopy. Gastrointestinal Endoscopy. 2019;90(1):55-63.
29. Yu KH, Beam AL, Kohane IS. Artificial intelligence in healthcare. Nature Biomedical Engineering. 2018;2(10):719-731.
30. Albahri AS, et al. IoT-based telemedicine for disease prevention and health promotion: State-of-the-Art. Journal of Network and Computer Applications. 2021; 173:102873.
31. Rong G, et al. Artificial intelligence in healthcare: Review and prediction case studies. Engineering. 2020;6(3):291-301.
32. Erickson BJ, et al. Machine learning for medical imaging. Radiographics. 2017;37.
33. Sande D, et al. Developing, implementing and governing artificial intelligence in medicine: A step-by-step approach to prevent an artificial intelligence winter. BMJ Health Care Inform. 2022;29.
34. Kolberg D, Zühlke D. Lean automation enabled by industry 4.0 technologies. IFAC-Papers Online. 2015;48.
35. Stöger K, Schneeberger D, Holzinger A. Medical artificial intelligence: The European legal perspective. Communications of the ACM. 2021;64(11): 34-36.
36. Li RC, Asch SM, Shah NH. Developing a delivery science for artificial intelligence in healthcare. NPJ Digital Medicine. 2020; 3(1):107.
37. Markus AF, Kors JA, Rijnbeek PR. The role of explainability in creating trustworthy artificial intelligence for health care: A comprehensive survey of the terminology, design choices, and evaluation strategies. Journal of Biomedical Informatics. 2021; 113:103655.
38. Topol EJ. High-performance medicine: The convergence of human and artificial intelligence. Nature Medicine. 2019;25(1): 44-56.
39. Hleg A. Ethics guidelines for trustworthy AI. B-1049 Brussels. 2019;6.
40. He J, et al. The practical implementation of artificial intelligence technologies in medicine. Nature Medicine. 2019;25(1):30-36.
41. Ahmad MA, Eckert C, Teredesai A. Interpretable machine learning in healthcare. in Proceedings of the 2018 ACM international conference on bioinformatics, computational biology, and health informatics; 2018.
42. AI H. High-level expert group on artificial intelligence. Ethics guidelines for trustworthy AI. 2019;6.
43. Andrada G, Clowes RW, Smart PR. Varieties of transparency: Exploring agency within AI systems. AI and Society. 2023;38(4):1321-1331.
44. Kritikos K, Skrzypek P. A review of serverless frameworks In: 2018 IEEE/ACM International Conference on Utility and Cloud Computing Companion (UCC Companion). 2018;161–168. Available:https://doi.org/10.1109/UCC-Companion.2018.00051
45. Ast M, Gaedke M. Self-contained web components through serverless computing, in Proceedings of the 2nd International Workshop on Serverless Computing (WoSC '17). Association for Computing Machinery: New York; 2017.
46. Li B. Trustworthy AI: From principles to practices. ACM Comput. Surv. 2023;55.
47. Smuha NA. The EU approach to ethics guidelines for trustworthy artificial intelligence. Computer Law Review International. 2019;20(4):97-106.
48. Chatila R, Havens JC. The IEEE global initiative on ethics of autonomous and intelligent systems. Robotics and well-being. 2019;11-16.
49. Arrieta AB, et al. Explainable Artificial Intelligence (XAI): Concepts, taxonomies, opportunities and challenges toward responsible AI. Information Fusion. 2020; 58:82-115.
50. Leng K, Chen X. A genetic algorithm approach for TOC-based supply chain coordination. Appl Math Inform Sci. 2012; 6.
51. Reddy S. Artificial intelligence and healthcare—why they need each other? J Hosp Manag Health Policy. 2020;5.
52. Hahn A, et al. Cyber-physical security Testbeds: Architecture, application, and evaluation for smart grid. IEEE Trans Smart Grid. 2013;4.
53. Zhavoronkov, A., Caution with AI-generated content in biomedicine. Nat Med, 2023. 29.
54. La HJ, Kim SD. A service-based approach to designing cyber physical systems; 2010.
55. Leonard TC, Richard H, Thaler, Cass R. Sunstein, nudge: Improving decisions about health, wealth, and happiness. Constit Polit Econ. 2008;19.
56. Ayers JW, et al. Comparing physician and artificial intelligence chatbot responses to patient questions posted to a public social media forum. JAMA Intern Med. 2023;183.

57. Kambatla K, et al. Trends in big data analytics. J Parallel Distrib Comput. 2014;74.
58. Ziegelmayer S, Reischl S, Havrda H. Development and validation of a deep learning algorithm to differentiate colon carcinoma from acute diverticulitis in computed tomography images. JAMA Netw Open. 2023;6.
59. Lin NU, Bichkoff H, Hassett MJ. Increasing burden of prior authorizations in the delivery of oncology care in the United States. J Oncol Pract. 2018;14.
60. Steiner DF, Nagpal K, Sayres R. Evaluation of the use of combined artificial intelligence and pathologist assessment to review and grade prostate biopsies. JAMA Netw Open. 2020;3.
61. Chaiyachati KH, Shea JA, Asch DA. Assessment of inpatient time allocation among first-year internal medicine residents using time-motion observations. JAMA Intern Med. 2019;179.
62. Lee J, Kao HA, Yang S. Service innovation and smart analytics for industry 4.0 and big data environment. Procedia CIRP. 2014; 16.
63. Lång K, Josefsson V, Larsson AM. Artificial intelligence-supported screen reading versus standard double reading in the Mammography Screening with Artificial Intelligence trial (MASAI): A clinical safety analysis of a randomised, controlled, non-inferiority, single-blinded, screening accuracy study. Lancet Oncol. 2023;24.
64. Abràmoff MD, et al. Pivotal trial of an autonomous AI-based diagnostic system for detection of diabetic retinopathy in primary care offices. Npj Digit Med. 2018;1.
65. Brass I, et al. Standardising a moving target: The development and evolution of IoT security standards. Living Internet Things. 2018;24.
66. Brettel M, et al. Enablers for self-optimizing production Systems in the Context of Industrie 4.0. Procedia CIRP. 2016;41.
67. Desai AN. Artificial intelligence: Promise, pitfalls, and perspective. JAMA. 2020;323.
68. Esteva A, et al. Dermatologist-level classification of skin cancer with deep neural networks. Nature. 2017;542(7639): 115-118.
69. Li W, et al. E-leadership through strategic alignment: An empirical study of small- and medium-sized enterprises in the digital age. J Inf Technol. 2016;31.
70. Zohny H, McMillan J, King M. Ethics of generative AI. J Med Ethics. 2023;49.
71. Takefuji Y. A brief tutorial on generative AI. Br Dent J. 2023;234.
72. Ramgopal S, et al. Artificial intelligence-based clinical decision support in pediatrics. Pediatr Res. 2023;93.
73. Oduoye MO, et al. Impacts of the advancement in artificial intelligence on laboratory medicine in low- and middle-incomecountries: Challenges and recommendations-A literature review. Health Sci Rep. 2024;7.
74. Jazdi N. Cyber physical systems in the context of industry 4.0, in 2014 IEEE international conference on automation, quality and testing, robotics; 2014.
75. Rajkomar A, Dean J, Kohane I. Machine learning in medicine. N Engl J Med. 2019; 380.
76. Yang J, et al. Artificial intelligence applications in the treatment of colorectal cancer: A narrative review. Clin Med Insights Oncol. 2024;5.
77. G20 New Industrial Revolution Action Plan; 2016.
78. Glaser BG, Strauss AL. The discovery of grounded theory : Strategies for qualitative research. Abingdon: Routledge; 1967.
79. The Industrial Internet of Things, Volume B01: Business Strategy and Innovation Framework; Industrial Internet Consortium; 2016.
80. Jensen JC, Chang DH, Lee EA. A model-based design methodology for cyber-physical systems; 2011.
81. Koçak B, et al. Must-have qualities of clinical research on artificial intelligence and machine learning. Balkan Med J. 2023;40.
82. Manne, Ravi, Sneha C, Kantheti. Application of artificial intelligence in healthcare: Chances and challenges. Current Journal of Applied Science and Technology. 2021;40(6):78-89. Available:https://doi.org/10.9734/cjast/2021/v40i631320.
83. Panesar A. Machine learning and AI for healthcare. Coventry, UK: Apress; 2019.
84. Esmaeilzadeh P. Use of AI-based tools for healthcare purposes: A survey study from consumers' perspectives. BMC Medical Informatics and Decision Making. 2020; 20:1-9.
