

Research Article

The Role of AI in Transforming Healthcare: Ethics, Integration, and Global Impact

Nnenna Favour Onuzuruike¹, Konstantin Koshechkin², Oluwatoyin Rachael Taiwo¹, Oluwasetemi Ojedayo Ojekunle¹, Ada Glory Chukwu¹, Chisom Peace Ezeamaku-Humphrey¹, Patrick Chidera Gift³ and ThankGod Chimenem Kalagbor^{1*}

¹Department of Public Health, Healthcare First Moscow State Medical University named after I.M. Sechenov, Moscow, Russia.

²Department of Digital Medicine, First Moscow State Medical University named after I.M. Sechenov, Moscow, Russia.

³Department of Management of Nursing, People's Friendship University named after P.L. Moscow, Russia.

Corresponding Author: ThankGod Chimenem Kalagbor, Department of Public Health, Healthcare First Moscow State Medical University named after I.M. Sechenov, Moscow, Russia.

Received: 📅 2025 June 06

Accepted: 📅 2025 June 26

Published: 📅 2025 July 08

Abstract

The global healthcare system currently undergoes significant challenges that negatively affect patient experience such as the rising costs of healthcare, the manual processes of traditional healthcare that leads to wastage of time and increases waiting time for sick patients, limited number of healthcare practitioners and doctors, and the rising incidents of chronic diseases underwhelming the capacity of healthcare organisations globally. While efforts are currently underway to address these challenges, reports predict the increasing impact of these challenges in the future. However, as current applications of AI in healthcare have shown, the integration of AI algorithms in healthcare practices has the potential to drastically address these challenges in a manner that will positively increase the overall experience of patients in global healthcare systems. The primary aim of the research is to examine the current landscape of AI integration in healthcare and possible pathway for the future. Using systematic literature review, it examines scholarly literatures from reputable journals and databases. The research finds that while there are ethical and integration challenges plaguing the application of AI in healthcare, AI technologies are currently being used in different facets of healthcare such as imaging, diagnostics, predictive analytics, and recommendations. The research recommends the training of healthcare practitioners and doctors on the mechanisms of AI, the creation of uniform regulations and regulatory agencies to create standards in the industry, and strict adherence to ethical guidelines before applying AI to healthcare.

Keywords: Artificial Intelligence, Healthcare, Algorithms, Technology, Ethical Issues, Integration Challenges

1. Introduction

Globally, healthcare systems are facing systematic obstacles that challenge their ability to effectively advance health of the population, improve patients' experience and significantly reduce the rising costs of effective healthcare [1-3]. Among other things, factors such as, increasing burden of chronic ailments, ageing population are highlighted as one of the most crucial systemic challenges facing governments globally. While healthcare systems around the world had struggled to provide optimum care experience for their ageing and sick population, the pandemic exacerbated these challenges and exposed the critical incapability of existing healthcare frameworks to cater for the evolving nature of healthcare risks and ailments. For example, the World Health

Organisation estimates that by 2030, there will be 18 million fewer healthcare professionals and 5 million fewer doctors than the world requires [4]. Such shortage is expected to be particularly worse in developing countries.

The grim potential of healthcare systems around the world highlights the importance of the integration of technology into the fabrics of these systems. This is particularly so as the technology of Artificial Intelligence (AI) and the promise it holds show the promising future of healthcare if combined with technology. For example, the increasing competence of cloud computing is enabling the smooth integration of AI technologies into traditional healthcare frameworks [5]. A practical example in this context is the current capacity of

cloud computing to process large datasets in record time and with lower costs as against the traditional systems of healthcare which require more time and higher costs. In fact, there is an increasing number of technology providers entering into partnerships with healthcare organisations to utilise AI-powered models supported by cloud computing to drive medical innovation and transformation [6]. This is just a single use case of the transformative power of AI if integrated in healthcare systems.

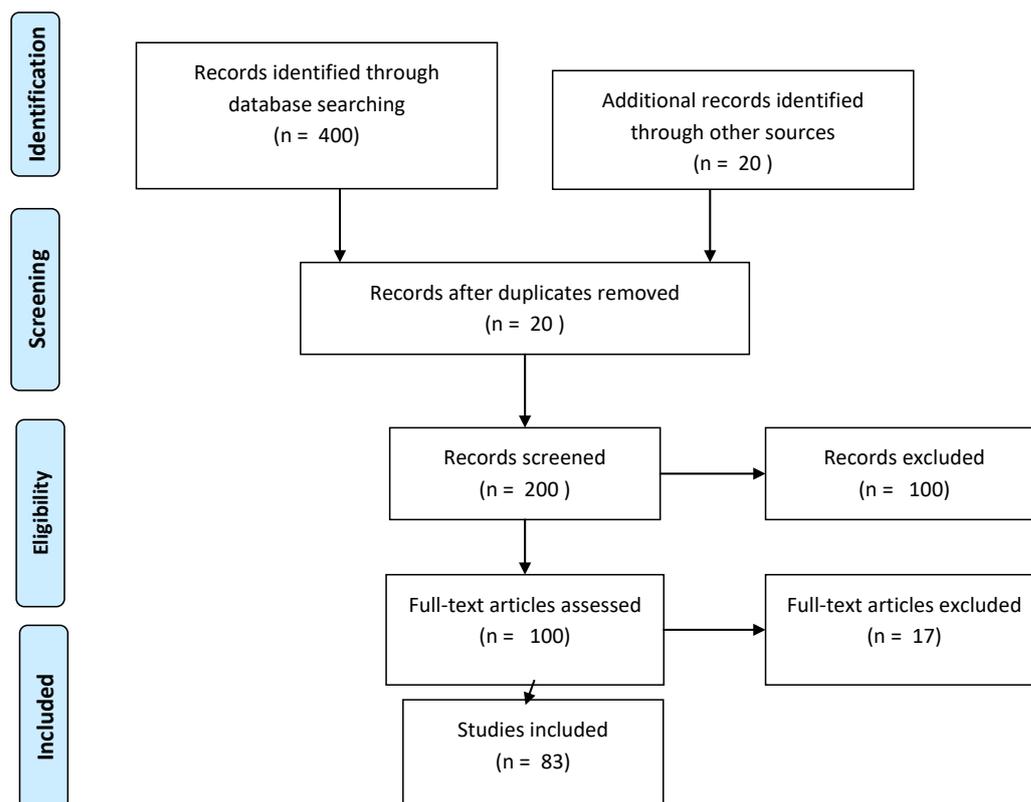
Generally, AI is revolutionising the frameworks and systems of healthcare globally through innovative technologies such as precise diagnostics, personalised treatment plans, predictive analytics among others. However, while the technology of AI holds the promise for transforming healthcare system and subduing impending challenges in the system, it also runs the risk of ethical violation of certain patient rights if not applied and managed properly. Unlike other utilities of AI technologies, its use in healthcare presents potential issues and challenges such as, data privacy, fairness, accountability, trust among others. This is particularly due to the requirement of AI models to make use of personal health information of patients to train its algorithm [7]. Hence, there is the risk of exposure of sensitive patient data and the safety of patients if ethical considerations are not highlighted and integrated in the entire process. These ethical issues highlight the importance of developing a broad ethical framework to guide the integration of AI technologies into healthcare systems globally [8]. In fact, with the rapid growth and sophistication of AI technologies and models, ethical considerations and frameworks have become rather urgent and of high necessity.

This article is a systematic interrogation of the role of AI in transforming healthcare systems globally. It explores the concept of AI, its technologies and current applications in healthcare. It also examines ethical considerations in the implementation of AI in healthcare and other related issues. Furthermore, it interrogates how AI is currently being integrated in healthcare systems and the potential for growth. Moreover, the article highlights the current impact of AI integration in healthcare systems globally. The aim is to achieve a pedantic and thorough appreciation of the topic

with the intent to educate and inform.

2. Material and Methods

This article employed the systematic approach of literature to examine the transformational role of AI in healthcare systems. The search strategy encompassed a pedantic examination of electronic databases, including IEEE, PubMed, Scopus, Google Scholar, and Embase, utilising the combination of key search terms. The combined key search terms include, "artificial intelligence," "AI," "healthcare," "AI AND transformational healthcare," "AI AND healthcare systems" among others. The Boolean strategy (AND, OR) were utilised to tailor the search strategy in order to make sure it is within the objectives of this research. The inclusion criteria encompassed peer-reviewed articles published in English between 2014 and 2025, with a specific focus on the application of AI in healthcare and its challenges. This timeframe was chosen for this research as it marked the era in which AI received significant adoption and application in healthcare. It also witnessed the emergence of recent issues surrounding the integration of AI in healthcare. Thus, it is important that this timeframe is particularly focused on. The articles were screened based on their relevance to this research such as the meaning of AI, its current application in healthcare, ethical issues surrounding this application, and integration challenges faced in the application of AI in healthcare. The exclusion criteria were relevant articles which were published before 2014, non-peer-reviewed articles, and those which are not relevant to the objectives of this research. The systematic search strategy yielded a total of 400 articles across the selected electronic databases, as follows. PubMed: 100 articles; Scopus: 80 articles; Google Scholar: 100 articles; IEEE: 60 articles; Embase: 60 articles. After initial screening of the articles based on the relevance of the titles and abstracts of the articles, those that met the inclusion criteria of this research were subjected to full-text review. Across all the electronic databases, a total of 200 articles were screened, which resulted in the exclusion of 100 articles based on predefined criteria. Subsequently, the remaining 100 articles were subjected to full-text review. Through a pedantic review process, 83 peer-reviewed articles that are directly relevant to the different facets of this discourse were selected.



3. Discussion

3.1 Overview of AI in Healthcare

3.1.1 The Concept of AI and its Types

AI simply refers to the systematic process or science of developing intelligent machines [9]. These machines are developed through trained datasets or algorithms to think and act like humans for the purposes of learning and problem solving [9]. AI systems are built to be proactive rather than reactive as they anticipate problems based on existing datasets and they provide intelligent solutions to those problems [10]. The core of AI's abilities and its strength lies in its capacity to learn from existing datasets and make accurate predictions [11]. A practical example is the ability of AI to accurately predict or diagnose the medical issue of a patient based on the medical history of such patient. Its key advantage also lies in its ability to be dynamic yet adaptable, constantly learning from available datasets thereby constantly reinventing its relevance [12]. While AI has emerged has an umbrella for various futuristic and smart technical models, it is made of different technologies which can be considered as its subfields. They include the following: Machine Learning (ML), Deep Learning (DL), and Natural Language Processing (NLP). ML simply refers to the study of algorithms that allow computer programmes to automatically improve their experience [13]. ML is further divided into 'supervised,' 'unsupervised' and 'reinforcement learning' (RL). There is also further research on the possibility of further dividing ML into 'semi-supervised,' 'self-supervised' and 'multi-instance' (ML).

It has been explained that supervised learning utilises labelled data for find solutions to problems [14]. A practical

example in the context of healthcare is utilising labelled X-ray images of commonly recognised tumours to detect tumours in new images. On the other hand, unsupervised learning extracts information from data without labels [15]. An example under this context is the grouping of patients with common symptoms in order to detect a probable cause. In reinforcement learning, computational agents learn by trial and error, or by expert demonstration. The algorithm learns by developing a strategy to maximise rewards. However, deep learning is a class of algorithms that learns by using a large, many-layered collection of connected processes and exposing these processors to a vast set of examples [16]. Deep learning is the most used form of AI currently with the technology transforming everyday things such as images and speech recognition [17]. For natural language processing (NLP), it helps AI systems to generate and interpret human language, with its use in healthcare ranging from clinical documentation, chatbot-based symptom checkers, and extraction of relevant information from electronic health records [18]. Overall, the use of these AI systems in healthcare include: ML for predictive analytics, DL for advanced image recognition in diagnostics, and NLP for the extraction of relevant information from raw medical data and the automation of decision-making in patient care [19]. Altogether, these systems are geared towards improving patient experience, saving costs, and time.

3.2 Current Applications of AI in Healthcare

AI systems are currently employed in healthcare to drive transformation and innovation in patient care. While this section of the article highlights certain current use cases of AI in healthcare, it is important to note that the list is not

exhaustive as the use cases continue to expand and accelerate every day. These use cases transcend beyond physical health into mental health. They include the following.

3.3 Precision Diagnostics (Diagnostic Imaging)

One of the most common representations of AI in healthcare currently is the development of automated classified medical images. An instant example is the recent finding that 58% and 53% of AI/ML-based medical devices approved in the United States of America (USA) and Europe respectively between 2015 and 2020, were for radiological purpose [20]. Recent studies predict that AI's ability to produce image-based diagnoses will soon outpace that of human experts with considerable years of experience and specific expertise in the process [21]. It has also been highlighted that the ability of AI systems to produce these image-based diagnoses cut across diverse medical areas such as, pneumonia in radiology (an AI-system trained with labelled frontal chest X-ray images was found to outpace the performance of expert radiologists in detecting pneumonia) [22], dermatology (an AI system trained with clinical images was found to classify skin lesions accurately) [23], cardiology (an AI system trained was found to diagnose heart attack with such accuracy that is comparable to the best cardiologists) [24] among others. There are more applications of AI in diagnostic imaging undergoing research with its accuracy being tested. The current applications highlighted above are just miniscule to what is currently obtainable in the field intersecting AI and healthcare.

3.4 Diabetic Retinopathy Screening

The primary method of avoiding loss of vision as caused by diabetes is early detection and treatment of diabetic retinopathy. However, in order to detect this ailment, an individual must undergo screening which has been noted as particularly expensive due to the limited number of persons with expertise in eye care vis-à-vis the growing number of persons with diabetes [25]. Thus, the screening process requires significant amount of money due to the high demand from diabetic patients, yet low supply of eye care professionals. However, recent researches and clinical testing on the integration of AI in the screening and detection of diabetic retinopathy have found positive performance from the technology with significantly lower costs compared to traditional screening [26]. Furthermore, the Food and Drug Administration of the USA recently approved an AI system, "IDx-DR" which was found to demonstrate 87% sensitivity and 90% specificity in detecting over 50% mild diabetic retinopathy [6].

3.5 Improving Precision and Reducing Waiting Timings for Radiotherapy Planning

A fundamental use case of AI currently is its application for image preparation and planning tasks for healthcare professionals involved in radiotherapy cancer treatment. Traditionally processes involved in the image preparation requires extended amount of time with laborious work demanded of an oncologist who makes use of uniquely designed software to draw contours around the regions of interest [27]. However, recent tests show that the application

of AI in this process reduces time wastage by 90% [28]. The implication of this is the reduction of waiting times as is the case in traditional healthcare. Such reduction in the waiting time could prove important to saving a patient's life.

3.6 AI-supported Drug Discovery

Clinical researches have highlighted that AI is transforming the processes of clinical trial design and optimisation of drug manufacturing processes [29]. A frequently highlighted example is the recent announcements by DeepMind and AlphaFold, which highlights the development of AI systems that understand disease processes better, predict protein structures and develop more targeted therapeutics [30].

3.7 Virtual Assistants and AI Chatbots

AI-powered chatbots are driving improved patient experience in healthcare. Chatbots such as Babylon and Ada are increasingly being employed by patients to identify diseases through symptoms and recommend further medical actions [6]. These chatbots are transforming the frameworks and systems of primary and community medicine. Furthermore, technology companies are integrating these AI chatbots into wearable devices to provide instant medical insights to patients and caregivers with the overall aim of improving their experience and cutting medical costs [6].

3.8 Ambient and Intelligent Care

There is currently an emergence of AI-driven technologies which are driving ambient and intelligent care in the healthcare industry. A current example is Emerald, a wireless, touchless sensor and ML platform for remotely monitoring sleep, breathing and behaviour [6]. There is also Google Nest, which is built to monitor sleep using motion and sound sensors [31]. Furthermore, there is also increasing interest in the development smart speakers which employ the technology of AI to monitor heart rhythms without contact [32]. Altogether, these AI systems and their use cases target the improvement of population health, improved patient experience, and reduction of medical costs. The aim is to flatten the scope of difficulties that could potentially arrest the development of healthcare systems globally. While there has been significant improvement in the past decade as to the development of AI systems and their integration into health systems, more of these systems are being tested and are being rolled out if approved. However, although, such technological development vis-à-vis healthcare systems should be applauded, there has been call for caution to the full implementation of these technologies due to the potential risks and dangers AI represents in healthcare. One of such risks is the issue of data privacy and confidentiality of sensitive health information of patients. The next section of this article critically assesses these issues with a balance to highlighting the need for balance in the integration of AI in healthcare systems.

3.9 Ethical Considerations

In order to holistically examine ethical considerations in AI as it concerns healthcare systems, the following issues are examined.

4. Data Privacy and Patient Protection

One of the primary ethical concerns in the integration of AI in healthcare systems is the protection sensitive medical data and safeguard of the patient from violation of right to confidentiality. Due to the nature of the industry, healthcare systems are given access to large amount of medical data and information belonging to patients. On the other hand, AI is powered by access to these medical data and information held by healthcare systems in order to train and validate their systems. However, overtime, concerns emerged as to whether this access to sensitive patient data breaches data privacy and confidential rights of the patients [18]. In fact, these concerns transcend beyond mere access to these sensitive data but encompasses whether the data are being used and handled responsibly. In compliance with the provisions of legal frameworks on data protection such as the General Data Protection Regulation (GDPR) of the European Union (EU) and similar legal frameworks in other jurisdictions, health organisations are mandated to ensure that data of patients are collected, stored, and processed with utmost care and responsibility. These legal frameworks on data protection also provide that data must be collected unless when authorised and failure to do so results in violation of the right of the patient's confidentiality, potential crime of identity theft, or breach of the patient's autonomy [33]. These violations have serious consequences against a healthcare organisation or data processor found culpable.

However, in order to address these concerns, stakeholders involved in the integration of AI in healthcare are advised to implement strong data security protocols and rails that protect patient data from the acquisition phase to the storage and algorithm and deployment phase [34]. Healthcare organisations are also encouraged to adopt data minimisation and anonymisation strategies in order to reduce the exposure of sensitive patient data and to avoid the ethical risks associated with AI integration [34]. Also, healthcare organisations are mandated to comply with the provisions of legal frameworks on data protection such as the GDPR and other legal frameworks in other jurisdictions that mandate the protection of data privacy and patient confidentiality. These legal frameworks are possessed with legal and ethical guidelines on how to collect the data of persons (patients in this case), how to store them, and use them. Failure to abide to these frameworks is met with stringent penalties. Furthermore, the importance of transparency is highlighted. In addition to compliance with established legal frameworks on data protection, health organisations are encouraged to be transparent to patients on the use of their personal data for training AI algorithms. Specifically, health organisations have the responsibility to provide adequate information to the patients on how their data will be used or handled, potential risks involved in the entire process, and protective frameworks that have been established and adhered to for safeguarding their data [35].

4.1 Algorithmic Bias and Fairness

Algorithmic bias and its implication on fairness is another fundamental ethical consideration that concerns the application of AI in healthcare. The nature of AI and the

processes involved in its training makes it prone to the following bias: race, sex, political ideologies, socio-economic status among others. In the context of healthcare, such bias might be stem from improper training of datasets that consequently fail to adequately represent diversity or nuances in the patient population used as datasets [36]. Algorithmic bias of AI systems poses significant ethical risks in healthcare as it can lead to divergences in diagnosis, treatment, and outcomes among different patient groups [37]. A practical example in the context of this research is where data collected from a particular patient group in order to train AI algorithm is unrepresentative of other predominantly unrepresented populations. In such an instance, the AI systems will be prone to misdiagnoses and bias against the unrepresented populations. This is the same with predictive AI systems trained with socio-economic datasets of targeted populations to the detriment of other unrepresented groups, which might lead to disparities in access to care or resource allocations [38]. Such bias further worsens the gap sought to be closed between populations in accessing healthcare services.

It is important to note that if left unfettered, algorithmic bias has the potential to violate the important principles of fairness, justice, and equity in healthcare [39]. Such act will only further worsen systemic discrimination and disregard to marginalised groups and populations that is already prevalent in traditional healthcare systems. Hence, the implications of algorithmic bias is not just nestled in the individual disregard it perpetuates, but also its broader implications in the society such as, inequality, lack of fairness, systemic discrimination among others [40]. However, in order to reduce the incidents of algorithmic bias in the development of AI systems, a multi-headed approach is required. First, healthcare organisation must ensure that its available datasets are representative of every group and population under it. This means that the training datasets in which it makes available for developing AI systems must be adequately representative of different socio-economic background, race, culture among others [41]. This entails intentionally accessing datasets that are historically underrepresented, promoting inclusivity in the datasets it seeks to be used for training AI models, and utilising data augmentation and techniques to address imbalances [42].

However, healthcare organisations are not saddled with the sole responsibility to avoid this bias. Algorithm developers also have important role to play by employing algorithm fairness strategies to identify and reduce potential biases in AI models. These fairness strategies include the following: fairness-aware training algorithms, such as demographic parity or equalised odds, whose primary goal is to enhance the performance of fairness in models, and post-processing methods, which adjust model outputs to reduce disparate impacts on different groups [41]. Furthermore, algorithm developers are also encouraged to incorporate techniques that can identify and highlight bias in algorithmic decision-making. These strategies are important to identify the origin of biases and how they can be handled when developing AI algorithms. Furthermore, it is also important that frequent

audits and examination of AI algorithms are carried out in order to observe and potentially identify discrimination in healthcare outcomes. This is essential to ensuring that these algorithms operate without biasness over time. Hence, it is also important that healthcare organisations employ ongoing monitoring systems that will ensure fairness of AI models being applied to healthcare systems. For example, a multidisciplinary team consisting of data scientists, healthcare professionals, and ethical experts could be set up by healthcare organisations to AI algorithms for possible bias and integrate correction actions [39]. These ongoing observation strategies are important for healthcare organisations to implement as they have a responsibility to uphold the principles of fairness, justice, equity, and non-discrimination. Also, the implementation of these strategies promotes inclusivity in the healthcare system which further fosters mutual trust and respect between patients and healthcare professionals. This is essential to not just addressing bias in AI algorithms but improving the experience of patients as they interact with the healthcare system.

4.2 Transparency and Accountability

In order to create trust and accountability in the healthcare system, practices must be seen to be transparent and explainable. This principle also holds true in the interaction of healthcare systems with AI, as the system and operations of the latter must be transparent in order to foster mutual trust between stakeholders involved in the entire process. The opaqueness and complexity of AI systems might complicate mutual trust between healthcare providers and AI developers as the former may struggle to understand the mechanisms involved in the operations of AI. Such struggle to comprehend the mechanisms of AI might create distrust among healthcare providers and water-down their excitement at integrating AI in healthcare systems [43]. Transparency and accountability are important concepts in healthcare. They ensure that vital information is open and accessible so as to inform decision-making. These concepts also drive interaction between healthcare providers and patients. This also holds true in the interaction between healthcare providers and AI developers as important information about AI systems and algorithms must be open and accessible for the former in order to aid their decision-making. Transparency and accountability are important in the relationship between healthcare and AI algorithms as it is determining factor for healthcare providers to trust the diagnoses and predictive analytics of these algorithms [44].

In order to foster transparency and accountability in the implementation of AI systems in healthcare, it has been suggested that the outcome and recommendations of these systems are interpretable and explainable to the healthcare providers [45]. A fundamental way to doing this is to employ model interpretability techniques that give broad explanations and interpretations to components of AI algorithmic predictions. Model interpretability techniques such as, feature importance analysis, partial dependence plots, and local interpretable model-agnostic explanations (LIME) have been suggested as they can help

inform healthcare providers on AI algorithms arrive at health-based decisions [46]. However, the responsibility to providing transparency and accountability does not only lie with AI developers. Healthcare organisations also have important role to play as they can prepare and provide transparency reports that detail the entire chain of AI models implementing in its systems. The following information are expected to be found in such reports: datasets used to train the AI algorithms, algorithmic architecture and parameters, performance metrics, and potential limitations or caveats associated with algorithmic predictions [47]. Through such actions highlighting transparency and accountability, healthcare organisations can drive public confidence on the predictive analytics and recommendations of AI algorithms it implements. Furthermore, it is important that these reports, information, and even AI recommendations are disseminated in non-technical terms. This is important as healthcare providers and patients alike may not have the expertise or knowledge to interpret technical terms of AI algorithms. Hence, to boost trust and empower critical stakeholders in this context to interrogate the recommendations and results of AI algorithms, it is important that the language of AI predictions, its recommendations, and AI reports provided by healthcare organisations are disseminated and presented in non-technical language [48]. Thus, transparency and accountability in this context is a critical ethical consideration as the healthcare providers and patients are entitled to be adequately informed of the mechanisms of AI algorithms, its outcomes and recommendations in a manner that is open, accessible, and interpretable so as to inform critical personal decisions.

4.3 Autonomy and Informed Consent

Informed consent is the systematic communication between patients and healthcare providers in a manner that informs personal decision by the patient [49]. It includes concepts such as, capacity to make decisions, competency, ethical disclosure among others. Healthcare providers have ethical obligations to respect patients' right to be adequately informed of their health status, their diagnoses, treatment process, therapeutic success, test results, costs, and other vital information regarding their health [50]. Consequently, the informed consent of a patient must be gotten before any decision is made on any part that concerns the patient's health. A patient reserves the autonomy to make any decision that affects his/her health [51]. However, concerns about the autonomy of patients and their right to informed consent have increased with the rise of AI. In the case of healthcare and AI implementation, it is important to determine whether a patient consents to using AI in his/her treatment as is in line with the principle of autonomy. It has been highlighted that a patient may not want to be subjected to AI-assisted treatment or care and in such situation the autonomy of a patient must be respected [52]. Hence, healthcare providers are required to provide adequate information to a patient on the mechanisms of AI-assisted care and allow such patient to decide whether or not to allow the use of AI algorithms in his/her treatment. In this regard, healthcare providers are expected to intimate the patients on the following: treatment process, the risks of screening and imaging, data capture

anomalies, programming errors, privacy of their data and access control, strategies adopted for protecting genetic information obtained from the patients among other things [8]. Thus, patients can choose whether to allow AI-assisted treatment or not as it is within their right to do so.

4.4 Integration Challenges

This section of the article explores factors that pose as challenges to the successful integration of AI into healthcare systems. While some of these factors border on ethical issues, others are legal challenges and socio-cultural limitations. The next sub-sections critically interrogate these factors with the aim of informing change.

4.5 Ethical Issues

4.5.1 Data Ethics

As highlighted in the earlier sections of this article, data is the lifeblood of the development of AI algorithms. However, AI systems and their development are limited by the fundamental principles in healthcare such as informed consent, privacy and data protection, transparency, accountability among others. In order to successfully develop AI algorithms and models for healthcare systems, the data of patients (under the custody of healthcare providers) are needed to train these algorithms and models [53]. However, question as to who owns the patients' data have arisen with different jurisdictions such as Canada establishing through recent regulations that the data is owned by patients but that healthcare providers are custodians of the data [54]. Nevertheless, healthcare providers are increasingly providing access to these patients' health data in return for monetary compensation as evidenced in the recent transaction between the Royal Free London Foundation Trust and DeepMind [55].

Hence, recent events suggest that the development of AI algorithms for the healthcare industry has multi-layered safeguards that complicates the seamless interaction between both industries. These include: patient data protection rights, legal restrictions, and the guardianship of patients' medical data by healthcare providers which could prove expensive to navigate [56]. AI developers are reminded of the importance of navigating these restrictions within established legal and regulatory frameworks else they are subjected to significant consequences.

4.6 The Question of Fairness

As discussed in the earlier parts of this article, the question of fairness in the predictive analytics, recommendations, and outcomes of AI algorithms are important issues potentially limiting the adoption of AI in healthcare. It has been argued that this is a potent factor working against the mass adoption of AI in healthcare systems globally as datasets regardless of the rigour invested in accessing them are prone to bias to a certain extent based on gender, sexual orientation, race, sociologic, environmental, or economic factors [57]. Such element of bias is more pronounced in AI as the development of its algorithms is dependent on pre-existing datasets. More importantly, these pre-existing or available data have been found to be biased showing inequality in healthcare as

they suppress the medical data of historically marginalised populations [58]. A recent example is a study which highlighted that healthcare providers and professionals in the USA may have neglected the positive results of African Americans as they wrongly assumed that the model's positive predictive value for African Americans was low [58]. However, it was further found that the low positive rate was a consequence of the few African Americans who availed themselves to be participants in the initial research, therefore the possibility of false-positive results was high [58]. Also, there is the possibility of unjust discrimination by healthcare providers against certain category of persons [59]. Such marginalisation and discriminatory practices are consequently part of the datasets in which AI algorithms are trained with and it may pose certain risks to marginalised patients receiving AI-assisted care [60]. Another practical example is residents of rural areas in underdeveloped countries who have little to no access to established healthcare providers that are data pipelines to AI developers. In such instance, the AI algorithms are trained with potential bias against individuals from lower socio-economic backgrounds and even races.

4.7 The Challenge of Interpretability

The integration of AI to healthcare systems engenders the emergence of diverse challenges to clinicians [61]. While the efficiency of AI systems cannot be denied, a clinician under ethical obligation is better suited to make difficult practice decisions when necessary [62]. On the other hand, AI systems are prone to rely on bias findings when posed with making critical decisions. A practical example of a biased based-error of an AI system was where it categorised patients with pneumonia alone as high-risk while mistakenly categorising those with pneumonia and asthma as low-risk regardless of the fact that asthma exacerbates health risks in patients with pneumonia [63]. Also, there is the rising difficulty presented by the inability of clinicians to understand and explain the mechanisms of AI algorithms [64]. This is a fundamental challenge as the clinicians are not just passive users of these AI algorithms but are considered guardians of the machine [65]. Thus, regardless of whether a patient is subjected to AI-assisted care or not, the outcomes and recommendations are assumed to be certified by clinicians and they are consequently liable for the patient's experience [66]. The inability or difficulty to understand and interpret the mechanisms of AI algorithms poses ethical challenges to the clinicians as they are expected to be transparent and accountable in their relations with patients so as to drive informed consent on the part of the patient [67]. It is suggested that such difficulty pose the challenge of AI adoption by the clinicians as they might be forced not to subject themselves to unethical practices.

4.8 Legal Challenges

The qualification for licensed practice and employment of healthcare professionals are usually strict due to the nature of the job. They are also expected to be subjected to a set of codes that established ethical guidelines and behaviours expected of a healthcare professional. However, while the profession is strictly guided by these codes and

its professionals are prohibited from deviating from their tenets, there is currently no unified code or regulation established for governing the conduct of healthcare professionals in the application of AI [68]. With the rapid growth of AI and its increasing application in healthcare, the urgency of the development of a unified code of conduct as it involves the implementation of AI in healthcare cannot be overemphasised. However, it has been contended that the development of an AI code of conduct in healthcare practice must not be left to be the sole decision of lawyers or legislators, but must include AI developers with specific focus on developing algorithms for healthcare use [69]. Also, it is suggested that such code or regulation must specifically allocate proportion of faults among stakeholders involved in the development and implementation of these AI algorithms – that is, AI developers, manufacturers, users, and maintainers [70]. Furthermore, there is the need to review and update data privacy laws as current innovations in AI development outpace the provisions of current laws on data protection and privacy [71]. An example is the incompatibility of data protection laws previously considered to be progressive such as the HIPPA Act 1996 of the USA, which no longer serves current issues in the interaction between healthcare and AI [72]. Moreover, there is the issue of a lack of a globally-recognised regulatory agency that provides guidelines and standardisations for the application of AI algorithms in healthcare. This has led to the launch and approval of AI algorithms prone with faults and largely untested. A recent example is the NHS 111, a children's intelligent inquiry AI app supported by Babylon, which was approved by the Medicines and Healthcare products Regulatory Agency in the UK without thorough clinical testing on its efficacy and safety [73].

5. Issues Regarding Security

5.1 Hardware Security

AI products are dependent on electronic products such as computers, mobile phones, wearables among others to optimally perform their functions. However, such dependence raises important issues bordering on security. For example, it has been argued that while some of these electronic products are adequately secured, they are impacted by other factors such as cost, temperature variations, and electromagnetic interference [74]. Moreover, in the case of AI application in healthcare, it has been highlighted that clinicians currently lack practical expertise and knowledge in information technology and this makes it difficult for them to adequately operate multiple electronic products integrated with AI [75]. Furthermore, there is the issue of AI network security. The AI network security and its key nodes as currently structured have been emphasised to be subject to attacks that can send spiraling damages globally especially in sectors in which AI is being applied [76].

5.2 Software Security

Recent researches have shown that algorithm programmes regardless of their seeming protective frameworks are still subject to successful attacks [77]. Such attacks have the potential of undermining the performance or functions of AI systems globally. As recent researches have shown, the

sabotage of an AI algorithm by external can potentially affect the entire formative processes of such algorithm, exposing its datasets and architecture [78]. This is a significant concern as to the actual safety of datasets used by AI systems for the training of their algorithms. More worryingly, it has been found that such attacks can occur even if external actors are bereft of the knowledge of internal mechanisms of a targeted AI system [79]. Some of the implications of such attacks are that the original algorithm will gradually deviate from appropriate directions [80], missing data [81], and autonomous update errors [82].

5.3 Difficulty in Protecting Human Genetic Resources

While human genetic resources are fundamental to medical diagnoses processes and treatment, its application outside established frameworks presents dangerous outcome for humans. For example, the Ministry of National Defence of the People's Republic of China reported the existence of a biological weapon termed the "gene weapon," which is composed of bacteria, insects, and other microorganisms containing disease-causing genes which underwent genetic engineering modifications with catastrophic effects if deployed in warfare [56]. Additionally, it has been reported that there is the possibility of genetic mutation of specific ethnic groups if their genetic characteristics are studied [56]. These highlight the importance and urgency of protecting human genetic resources. Such importance and urgency are particularly amplified by the storage of genetic results of humans by healthcare organisations when people undergo genetic tests for diagnoses and treatment. Hence, there is the risk of these genetic results or the genetic data of patients becoming exposed if accessed by the wrong persons. This also poses significant risks to the adoption and integration of AI as the trust deficit around access and handling of patients' data become increasingly widened due to recent development surrounding how these resources are being used. Nevertheless, tightening legal frameworks on data privacy, especially as it concerns collection, storage, and transmission can help mitigate the incidences of genetic mutations and data violation.

5.4 Public Adoption

While there is a growing sensitization of the public on the capacity of AI algorithms and their potentials in transforming the traditional healthcare industry and practices as currently set up, there is still a gnawing trust deficit on both healthcare practitioners and patients on the actual impact of these algorithms and whether their mechanisms and outcomes can be trusted. In fact, patients still tend to trust the recommendations of healthcare practitioners and doctors more over machines regardless of the level of their accuracy. This might be due to the physical interaction involved in the healthcare relationship between healthcare practitioners and patients. Also, as this research has shown, there is still a significant deficit of knowledge and expertise on the part of healthcare practitioners on how AI algorithms work and the interpretability of their results. Such deficiency will further stifle the growth of public adoption of AI-assisted healthcare as the supposed "guardians" of these machines are still bereft of the mechanisms of their operations. Moreover, healthcare

practitioners in developing countries are still skeptical of the use of the AI in healthcare, as they fear that these machines might take-over their jobs in the nearest future [83].

6. Conclusion

AI is leading transformation in different industries and sectors across the globe. Its impact is also particularly seen in the healthcare sector as different AI-supported innovations are driving efficiency in predictive analytics, diagnoses, and recommendations in clinical practice. Through the instrumentality of AI-supported technologies, healthcare practice across the globe is improving the experience of patients and obliterating systemic challenges that threatened the future of global healthcare. For example, although healthcare reports estimate that there will be a significant shortage of healthcare practitioners and doctors as compared to the increasing number of patients with chronic ailments in the coming years, the advent of AI-supported technologies and AI-assisted care ensures possible balance in healthcare demand and supply in the future. Also, the integration of AI into healthcare practice among other things ensure the reduction of time needed for diagnoses and recommendations cutting down wait times and queues in hospitals and potentially saving lives. Its impact on healthcare costs is also significant as it is shown that the adoption of AI in healthcare can significantly reduce the burden of costs on patients. However, while the application of AI in healthcare has the potentials to transform the sector, there are ethical considerations that must be adhered to by healthcare providers and AI developers in order to protect patients. These ethical considerations include: data privacy and protection, bias and fairness, transparency and accountability, autonomy and informed consent of the patient. Failure to consider these ethical considerations gives rise to legal and ethical implications and questions on the safety of patients vis-à-vis AI application in healthcare.

Furthermore, although there are diverse emerging AI technologies that are being used and applied in healthcare with positive results, there are still factors that pose challenges to the full integration of AI in healthcare. These challenges stem from ethical and legal challenges, issues surrounding the security of hardware and software utilised for integrating AI in healthcare, and concerns about whether the data of patients are actually safe with AI manufacturers and developers as it has been shown that there is high possibility of these AI systems being exposed to attacks that can violate trained medical datasets. Nevertheless, the transformative power of AI in healthcare systems cannot be denied. In order to achieve the full potentials of AI in healthcare, it has been suggested that legal and ethical frameworks for accessing and handling patients' medical data must be constantly reviewed, updated, and tightened. Healthcare practitioners and physicians must also be trained in the mechanisms and operations of AI algorithms so as to inform mutual trust between them and patients on AI-assisted care. More policies, laws, regulations, and regulatory agencies must also be created to further establish and engender standards in the industry.

Reference

- Berwick, D. M., Nolan, T. W., & Whittington, J. (2008). The triple aim: care, health, and cost. *Health affairs*, 27(3), 759-769.
- Bodenheimer, T., & Sinsky, C. (2014). From triple to quadruple aim: care of the patient requires care of the provider. *The Annals of Family Medicine*, 12(6), 573-576.
- Feelay D. (2017). The triple aim or the quadruple aim? Four points to help set your strategy. *Institute for Healthcare Improvement*. <https://www.ihl.org/communities/blogs/the-triple-aim-or-the-quadruple-aim-four-points-to-help-set-your-strategy> (Accessed 25 May 2025)
- WorldHealthOrganisation. *Workingforhealthandgrowth: Investing in the health workforce*. <http://apps.who.int/iris/bitstream/10665/250047/1/9789241511308-eng.pdf> (25 May 2025)
- Lashinsky A. (2011). Tim Cook on how Apple champions the environment, education, and health care. *Fortune*. <https://fortune.com/2017/09/11/apple-tim-cook-education-health-care/> (25 May 2025)
- Bajwa, J., Munir, U., Nori, A., & Williams, B. (2021). Artificial intelligence in healthcare: transforming the practice of medicine. *Future healthcare journal*, 8(2), e188-e194.
- Singh, M. P., Keche, Y. N., & Keche, Y. (2025). *Ethical Integration of Artificial Intelligence in Healthcare: Narrative Review of Global Challenges and Strategic Solutions*. *Cureus*, 17(5).
- Farhud DD and Zokaei S. (2021). Ethical issues of artificial intelligence in medicine and healthcare. *Iran Journal of Public Health*, 50, i-v. doi:10.18502/ijph.v50i11.7600
- Xu, Y., Liu, X., Cao, X., Huang, C., Liu, E., Qian, S., ... & Zhang, J. (2021). Artificial intelligence: A powerful paradigm for scientific research. *The Innovation*, 2(4).
- Shukla Shubhendu, S., & Vijay, J. (2013). Applicability of artificial intelligence in different fields of life. *International Journal of Scientific Engineering and Research*, 1(1), 28-35.
- Bajwa, J., Munir, U., Nori, A., & Williams, B. (2021). Artificial intelligence in healthcare: transforming the practice of medicine. *Future healthcare journal*, 8(2), e188-e194.
- Xu, Y., Liu, X., Cao, X., Huang, C., Liu, E., Qian, S., ... & Zhang, J. (2021). Artificial intelligence: A powerful paradigm for scientific research. *The Innovation*, 2(4).
- Mitchell, T. M., & Mitchell, T. M. (1997). *Machine learning* (Vol. 1, No. 9). New York: McGraw-hill.
- Reardon, S. (2019). Rise of robot radiologists. *Nature*, 576(7787), S54-S58.
- Lasko, T. A., Denny, J. C., & Levy, M. A. (2013). Computational phenotype discovery using unsupervised feature learning over noisy, sparse, and irregular clinical data. *PLoS one*, 8(6), e66341.
- LeCun, Y., Bengio, Y., & Hinton, G. (2015). *Deep learning*. *Nature*, 521(7553), 436-444.
- Topol, E. J. (2019). High-performance medicine: the convergence of human and artificial intelligence. *Nature medicine*, 25(1), 44-56.

18. Farhud, D. D., & Zokaei, S. (2021). Ethical issues of artificial intelligence in medicine and healthcare. *Iranian journal of public health, 50*(11), i.
19. Singh, M. P., Keche, Y. N., & Keche, Y. (2025). Ethical Integration of Artificial Intelligence in Healthcare: *Narrative Review of Global Challenges and Strategic Solutions. Cureus, 17*(5).
20. Muehlematter, U. J., Daniore, P., & Vokinger, K. N. (2021). Approval of artificial intelligence and machine learning-based medical devices in the USA and Europe (2015–20): a comparative analysis. *The Lancet Digital Health, 3*(3), e195-e203.
21. Wang, X., Peng, Y., Lu, L., Lu, Z., Bagheri, M., & Summers, R. M. (2017). Chestx-ray8: Hospital-scale chest x-ray database and benchmarks on weakly-supervised classification and localization of common thorax diseases. In *Proceedings of the IEEE conference on computer vision and pattern recognition* (pp. 2097-2106).
22. Esteva, A., Robicquet, A., Ramsundar, B., Kuleshov, V., DePristo, M., Chou, K., ... & Dean, J. (2019). A guide to deep learning in healthcare. *Nature medicine, 25*(1), 24-29.
23. Bejnordi, B. E., Veta, M., Van Diest, P. J., Van Ginneken, B., Karssemeijer, N., Litjens, G., ... & CAMELYON16 Consortium. (2017). *Diagnostic assessment of deep learning algorithms for detection of lymph node metastases in women with breast cancer. Jama, 318*(22), 2199-2210.
24. Strodthoff, N., & Strodthoff, C. (2019). Detecting and interpreting myocardial infarction using fully convolutional neural networks. *Physiological measurement, 40*(1), 015001.
25. Bellema, V., Lim, Z. W., Lim, G., Nguyen, Q. D., Xie, Y., Yip, M. Y., ... & Ting, D. S. (2019). Artificial intelligence using deep learning to screen for referable and vision-threatening diabetic retinopathy in Africa: a clinical validation study. *The Lancet Digital Health, 1*(1), e35-e44.
26. Gulshan, V., Peng, L., Coram, M., Stumpe, M. C., Wu, D., Narayanaswamy, A., ... & Webster, D. R. (2016). *Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. jama, 316*(22), 2402-2410.
27. Oktay, O., Navanati, J., Schwaighofer, A., Carter, D., Bristow, M., Tanno, R., ... & Nori, A. (2020). Evaluation of deep learning to augment image-guided radiotherapy for head and neck and prostate cancers. *JAMA network open, 3*(11), e2027426.
28. Alvarez-Valle, J., & Moore, G. J. (2020). Project InnerEye open-source deep learning toolkit: Democratizing medical imaging AI.
29. Senior, A. W., Evans, R., Jumper, J., Kirkpatrick, J., Sifre, L., Green, T., ... & Hassabis, D. (2020). *Improved protein structure prediction using potentials from deep learning. Nature, 577*(7792), 706-710.
30. Team, A. (2020). AlphaFold: A Solution to a 50-year-old grand challenge in biology. *DeepMind, November, 30*.
31. Muoio, D. (2021). Google's next-gen Nest Hub debuts with contactless sleep monitoring and analysis features. *Mobi Health News, nd*.
32. Wang, A., Nguyen, D., Sridhar, A. R., & Gollakota, S. (2021). Using smart speakers to contactlessly monitor heart rhythms. *Communications biology, 4*(1), 319.
33. Murdoch, B. (2021). Privacy and artificial intelligence: challenges for protecting health information in a new era. *BMC medical ethics, 22*, 1-5.
34. Jaime, F. J., Muñoz, A., Rodríguez-Gómez, F., & Jerez-Calero, A. (2023). Strengthening privacy and data security in biomedical microelectromechanical systems by IoT communication security and protection in smart healthcare. *Sensors, 23*(21), 8944.
35. Naik, N., Hameed, B. M., Shetty, D. K., Swain, D., Shah, M., Paul, R., ... & Somani, B. K. (2022). Legal and ethical consideration in artificial intelligence in healthcare: who takes responsibility?. *Frontiers in surgery, 9*, 862322.
36. Naik, N., Hameed, B. M., Shetty, D. K., Swain, D., Shah, M., Paul, R., ... & Somani, B. K. (2022). Legal and ethical consideration in artificial intelligence in healthcare: who takes responsibility?. *Frontiers in surgery, 9*, 862322.
37. Prakash, S., Balaji, J. N., Joshi, A., & Surapaneni, K. M. (2022). Ethical conundrums in the application of artificial intelligence (AI) in healthcare—a scoping review of reviews. *Journal of personalized medicine, 12*(11), 1914.
38. Wójcik, M. A. (2022). Algorithmic discrimination in health care: an EU law perspective. *Health and human rights, 24*(1), 93.
39. Nazer, L. H., Zatarah, R., Waldrip, S., Ke, J. X. C., Moukheiber, M., Khanna, A. K., ... & Mathur, P. (2023). Bias in artificial intelligence algorithms and recommendations for mitigation. *PLoS digital health, 2*(6), e0000278.
40. Norori, N., Hu, Q., Aellen, F. M., Faraci, F. D., & Tzovara, A. (2021). Addressing bias in big data and AI for health care: A call for open science. *Patterns, 2*(10).
41. Pfeiffer, J., Gutschow, J., Haas, C., Möslin, F., Maspfuhl, O., Borgers, F., & Alpsancar, S. (2023). Algorithmic fairness in AI: an interdisciplinary view. *Business & Information Systems Engineering, 65*(2), 209-222.
42. Ueda, D., Kakinuma, T., Fujita, S., Kamagata, K., Fushimi, Y., Ito, R., ... & Naganawa, S. (2024). Fairness of artificial intelligence in healthcare: review and recommendations. *Japanese Journal of Radiology, 42*(1), 3-15.
43. Kiseleva, A., Kotzinos, D., & De Hert, P. (2022). Transparency of AI in healthcare as a multilayered system of accountabilities: between legal requirements and technical limitations. *Frontiers in artificial intelligence, 5*, 879603.
44. Bernal, J., & Mazo, C. (2022). Transparency of artificial intelligence in healthcare: insights from professionals in computing and healthcare worldwide. *Applied Sciences, 12*(20), 10228.
45. Tilala, M. H., Chenchala, P. K., Choppadandi, A., Kaur, J., Naguri, S., Saoji, R., ... & Tilala, M. (2024). Ethical considerations in the use of artificial intelligence and machine learning in health care: a comprehensive review. *Cureus, 16*(6).
46. Di Martino, F., & Delmastro, F. (2023). Explainable AI for clinical and remote health applications: a survey on tabular and time series data. *Artificial Intelligence Review, 56*(6), 5261-5315.

47. Shick, A. A., Webber, C. M., Kiarashi, N., Weinberg, J. P., Deoras, A., Petrick, N., ... & Diamond, M. C. (2024). Transparency of artificial intelligence/machine learning-enabled medical devices. *NPJ Digital Medicine*, 7(1), 21.
48. Amann, J., Blasimme, A., Vayena, E., Frey, D., Madai, V. I., & Precise4Q Consortium. (2020). Explainability for artificial intelligence in healthcare: a multidisciplinary perspective. *BMC medical informatics and decision making*, 20, 1-9.
49. AMA. (2024). *Informed consent*. <https://www.ama-assn.org/delivering-care/ethics/informed-consent> (Accessed 27 May 2025).
50. Markose, A., Krishnan, R., Ramesh, M., & Singh, S. (2016). A comparison of the sealing ability of various temporary restorative materials to seal the access cavity: An: in vitro: study. *Journal of Pharmacy and Bioallied Sciences*, 8(Suppl 1), S42-S44.
51. MacIntyre, M. R., Cockerill, R. G., Mirza, O. F., & Appel, J. M. (2023). Ethical considerations for the use of artificial intelligence in medical decision-making capacity assessments. *Psychiatry research*, 328, 115466.
52. Hasan, H. E., Jaber, D., Khabour, O. F., & Alzoubi, K. H. (2024). Ethical considerations and concerns in the implementation of AI in pharmacy practice: a cross-sectional study. *BMC Medical Ethics*, 25(1), 55.
53. Mittelstadt, B. D., & Floridi, L. (2016). The ethics of big data: current and foreseeable issues in biomedical contexts. *The ethics of biomedical big data*, 445-480.
54. Canadian Association of Radiologists (CAR) Artificial Intelligence Working Group. (2019). Canadian Association of Radiologists white paper on ethical and legal issues related to artificial intelligence in radiology. *Canadian Association of Radiologists' Journal*, 70(2), 107-118.
55. Powles, J., & Hodson, H. (2017). Google DeepMind and healthcare in an age of algorithms. *Health and technology*, 7(4), 351-367.
56. Jiang, L., Wu, Z., Xu, X., Zhan, Y., Jin, X., Wang, L., & Qiu, Y. (2021). Opportunities and challenges of artificial intelligence in the medical field: current application, emerging problems, and problem-solving strategies. *Journal of International Medical Research*, 49(3), 03000605211000157.
57. Geis, J. R., Brady, A. P., Wu, C. C., Spencer, J., Ranschaert, E., Jaremko, J. L., ... & Kohli, M. (2019). Ethics of artificial intelligence in radiology: summary of the joint European and North American multisociety statement. *Radiology*, 293(2), 436-440.
58. Drew, B. J., Harris, P., Zègre-Hemsey, J. K., Mammone, T., Schindler, D., Salas-Boni, R., ... & Hu, X. (2014). Insights into the problem of alarm fatigue with physiologic monitor devices: a comprehensive observational study of consecutive intensive care unit patients. *PLoS one*, 9(10), e110274.
59. Rajkomar, A., Hardt, M., Howell, M. D., Corrado, G., & Chin, M. H. (2018). Ensuring fairness in machine learning to advance health equity. *Annals of internal medicine*, 169(12), 866-872.
60. Char, D. S., Shah, N. H., & Magnus, D. (2018). Implementing machine learning in health care—addressing ethical challenges. *New England Journal of Medicine*, 378(11), 981-983.
61. Tobia, K., Nielsen, A., & Stremitzer, A. (2021). When does physician use of AI increase liability?. *Journal of Nuclear Medicine*, 62(1), 17-21.
62. Gelhaus, P. (2011). Robot decisions: on the importance of virtuous judgment in clinical decision making. *Journal of Evaluation in Clinical Practice*, 17(5), 883-887.
63. Nabi, J. (2018). How bioethics can shape artificial intelligence and machine learning. *Hastings Center Report*, 48(5), 10-13.
64. Basu, T., Engel-Wolf, S., & Menzer, O. (2020). The ethics of machine learning in medical sciences: Where do we stand today?. *Indian Journal of Dermatology*, 65(5), 358-364.
65. Beregi, J. P. (2018). Artificial intelligence and medical imaging 2018: French Radiology Community white paper. *Diagnostic and Interventional Imaging*, 99(11), 727-742.
66. Maliha, G., Gerke, S., Cohen, I. G., & Parikh, R. B. (2021). Artificial intelligence and liability in medicine: balancing safety and innovation. *The Milbank Quarterly*, 99(3), 629.
67. Afzal, S., & Arshad, A. (2021). Ethical issues among healthcare workers using electronic medical records: A systematic review. *Computer Methods and Programs in Biomedicine Update*, 1, 100030.
68. Mitchell, C., & Ploem, C. (2018). Legal challenges for the implementation of advanced clinical digital decision support systems in Europe. *Journal of clinical and translational research*, 3(Suppl 3), 424.
69. Cath, C. (2018). Governing artificial intelligence: ethical, legal and technical opportunities and challenges. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 376(2133), 20180080.
70. Kayaalp, M. (2018). Patient privacy in the era of big data. *Balkan medical journal*, 35(1), 8-17.
71. Golbus, J. R., Price, W. N., & Nallamotheu, B. K. (2020). Privacy gaps for digital cardiology data: big problems with big data. *Circulation*, 141(8), 613-615.
72. Jiang, L., Wu, Z., Xu, X., Zhan, Y., Jin, X., Wang, L., & Qiu, Y. (2021). Opportunities and challenges of artificial intelligence in the medical field: current application, emerging problems, and problem-solving strategies. *Journal of International Medical Research*, 49(3), 03000605211000157.
73. McCartney, M. (2018). Margaret McCartney: AI in medicine must be rigorously tested. *Bmj*, 361.
74. Pu, Y. F., Yi, Z., & Zhou, J. L. (2017). Defense against chip cloning attacks based on fractional Hopfield neural networks. *International Journal of Neural Systems*, 27(04), 1750003.
75. Lu, Z. M., & Li, X. F. (2016). Attack vulnerability of network controllability. *PLoS one*, 11(9), e0162289.
76. O'Sullivan, S., Nevejans, N., Allen, C., Blyth, A., Leonard, S., Pagallo, U., ... & Ashrafian, H. (2019). Legal, regulatory, and ethical frameworks for development of standards in artificial intelligence (AI) and autonomous robotic surgery. *The international journal of medical robotics and computer assisted surgery*, 15(1), e1968.

77. Mygdalis, V., Tefas, A., & Pitas, I. (2020). K-anonymity inspired adversarial attack and multiple one-class classification defense. *Neural Networks, 124*, 296-307.
78. Yuan, X., He, P., Zhu, Q., & Li, X. (2019). Adversarial examples: Attacks and defenses for deep learning. *IEEE transactions on neural networks and learning systems, 30*(9), 2805-2824.
79. Zhang, X., & Wu, D. (2019). On the vulnerability of CNN classifiers in EEG-based BCIs. *IEEE transactions on neural systems and rehabilitation engineering, 27*(5), 814-825.
80. Davis, S. E., Lasko, T. A., Chen, G., Siew, E. D., & Matheny, M. E. (2017). Calibration drift in regression and machine learning models for acute kidney injury. *Journal of the American Medical Informatics Association, 24*(6), 1052-1061.
81. Dawson, N. V., & Arkes, H. R. (1987). Systematic errors in medical decision making: judgment limitations. *Journal of General Internal Medicine, 2*(3), 183-187.
82. Nemati, S., Ghassemi, M. M., & Clifford, G. D. (2016, August). Optimal medication dosing from suboptimal clinical examples: A deep reinforcement learning approach. In *2016 38th annual international conference of the IEEE engineering in medicine and biology society (EMBC)* (pp. 2978-2981). IEEE.
83. Abdullah, R., & Fakieh, B. (2020). Health care employees' perceptions of the use of artificial intelligence applications: survey study. *Journal of medical Internet research, 22*(5), e17620.