The Impact of Artificial Intelligence on Health Outcomes: A Review

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ABSTRACT

Artificial intelligence (AI) has the potential to revolutionize healthcare by enhancing diagnostics, creating more tailored treatments, and streamlining healthcare administration. Focusing on peer-reviewed articles published in the past decade, a comprehensive literature search was undertaken using PubMed, Google Scholar, and IEEE Xplore. Some important results include the fact that AI can diagnose diseases and disorders as accurately as human specialists can, including skin cancer and diabetic retinopathy. For Instance, AI was able to detect diabetic retinopathy with a sensitivity rate of 97.5% and skin cancer with an accuracy rate of 72.1%. There was a 93% agreement between expert oncologists and AI-driven IBM Watson for Oncology recommendations for treatment optimization. Hospital readmissions for chronic diseases decreased by 22% when wearables powered by AI were used. The area under consideration (AUC-ROC) for AI models in healthcare management to forecast in-hospital mortality was 0.86. Despite these advantages, there are still problems that need to be resolved, including issues with data privacy and ethics, regulatory changes, and integration. That AI systems are open, equitable, and responsible is of the utmost importance. The key to a successful adoption is overcoming healthcare professionals' resistance through proper training. These are the areas where future AI research should focus for the technology to fulfil its healthcare potential.

Keywords: Artificial intelligence, Healthcare, Diagnostics, Treatment optimization, Patient monitoring, Healthcare management, Data privacy, Ethical considerations

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Introduction

The advent of AI has brought about substantial transformations in the field of healthcare and medical research. AI-driven deep learning and machine learning algorithms can be used to get better patient outcomes, more accurate diagnoses, and more effective treatment plans.[1] Realizing this transformation is possible because it can quickly and efficiently look at huge amounts of data. As a result, patients can get more personalized care and make smarter decisions. Many healthcare-related tasks could be made much easier with the help of artificial intelligence. Some of these are managing healthcare, giving medical care, diagnosing problems, and making treatments better. Wearable technology through artificial intelligence algorithms examines medical images more accurately.[2] It helps come up with personalized treatment plans and keeps an eye on patients' vital signs in real-time. These new ideas could help solve some of the most important problems in healthcare right now. One way they can help is by keeping doctors from making mistakes, improving care for patients with long-term illnesses, and making more accurate diagnoses.[3]

This article fills a gap in our knowledge of AI in healthcare by thoroughly investigating its effects on health outcomes and depicting a comprehensive picture of its present status. Adding to the existing body of knowledge, this review compiles the findings of multiple studies. The main arguments and moral concerns about AI are explored, along with some of the most important ways it can be used in medicine and diagnosis. There is also information in the article about how AI research can help fix problems in healthcare right now. More people want healthcare providers to cut costs, make their work easier, and give better care to their patients. AI could help solve these problems by automating administrative tasks, making it easier to guess how patients will do, and letting people get medical care and be watched from afar. This review explores how AI could make health outcomes better and fix issues that are already persistent in the health system. This paper is important for the field because it shows where AI is making a difference. Ethics issues, data privacy issues, and regulatory barriers need to be dealt, with for AI to be used effectively to get a more equitable healthcare system.

Literature Review

An ever-expanding body of literature explores the use of AI in healthcare. The reason behind this is the high level of interest and investment in this game-changing technology. Many aspects of healthcare have been improved by artificial intelligence (AI). Among these are more precise diagnoses, more effective treatments, enhanced patient care and monitoring, and more efficient healthcare administration.[4] This research explores the progress, debates, and the way forward for AI applications in healthcare. Any computer system or machine that learns, thinks, and acts like a brain is called artificial intelligence (AI).[5] After looking at medical data and making predictions based on those analyses, AI could make healthcare better. Better care for patients, faster diagnoses, and less work for office workers could all be made possible by this technology. That way, nurses and doctors will have more time to effectively treat the patients.[6]

In 2021, the worldwide AI healthcare market was worth over $11 billion, and by 2030, analysts project that number will rise to nearly $188 billion by 2030.[7] By the year 2021, nearly 20% of healthcare organizations worldwide had begun to use some form of artificial intelligence. Even though 25% of healthcare organizations have only just begun to integrate ML and AI into their processes. In 2021, the artificial intelligence software industry was largely driven by healthcare data integration and natural language processing.[8] The increasing use of artificial intelligence (AI) in healthcare is causing widespread concern,

according to a US survey, most notably regarding privacy and security.[9] Additional ethical considerations included safety issues and the potential for hostile entities to take control of the AI. A European survey found that patients have more faith in AI when it supplements human judgement rather than when it acts independently.[10] Although some potential patients have expressed concerns, the majority of healthcare executives believe that AI will improve healthcare facilities' capacity to treat patients and their overall quality of life.

Figure 1 shows the global distribution of AI model applications on different types of health data in 2021, broken down by adoption stage. The structured data derived from relational databases is most prominent, with a usage rate of 78% in the final stages and 80% in the beginning. With 73% of organisations using it in the early stage and 80% in the mature stage, natural language text is the second most common data type. Nearly 60% of early-stage companies and 43% of mature-stage companies use medical images. Nearly half of all startups and almost 40% of all established businesses use time series data. Less frequently used across all stages is audio/video data and other types of data, with little variation between stages. Across all stages of adoption, relational databases are heavily relied upon, and structured and textual data are preferred in AI health applications.

Diagnostic Accuracy

The use of deep learning models and other AI algorithms has completely altered the landscape of medical image diagnostics.[12] Standard diagnostic methods are very dependent on the knowledge and experience of the healthcare professionals who use them, so they are not always accurate. In contrast, AI algorithms, especially deep learning models, can consistently and correctly examine medical images.[13] They learnt from a huge number of tagged images, these models can find patterns and oddities that regular people might miss. Because of this feature, diagnostic workflows could run more smoothly, people would make fewer mistakes, and diagnostics would be more accurate. Artificial intelligence (AI) is better than humans at figuring out what things in pictures depict.[14] In a groundbreaking study, Esteva et al.[15] trained a deep convolutional neural network (CNN) to find a difference between the various kinds of skin cancer. It was able to diagnose skin cancer just as well as board-certified dermatologists (79% specificity and 91% sensitivity).

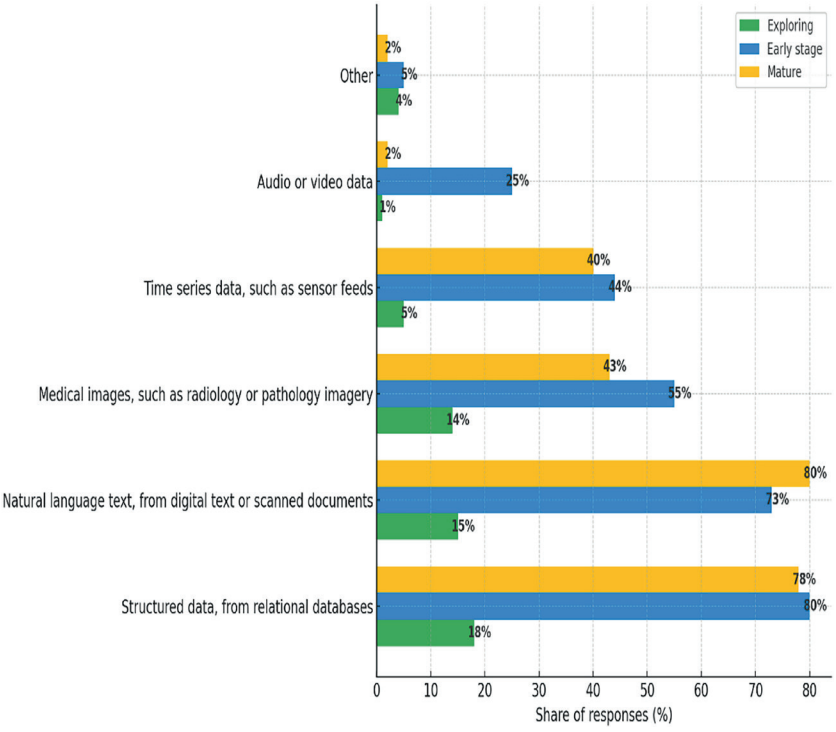

Fig 1 | Share of applications of AI models on health data worldwide by adoption stage

Source: Authors Development based on data extracted from Statista, 2024 (Stewart[11])

Another piece of evidence is that Gulshan et al.[16] trained a deep-learning algorithm that can spot diabetic retinopathy in images of the retinal fundus. There was a 97.5% chance that the algorithm would correctly identify this condition. Diabetes retinopathy kills a lot of people around the world. AI can help find and treat this condition much more quickly, as shown by these results. Using AI to read imaging studies like MRIs, CT scans, and mammograms has shown promise in the field of radiology.[17] McKinney et al.[18] found that a machine-learning algorithm that was trained to look at mammograms found breast cancer more accurately than human radiologists. The AI system cut down on false positives by 5.7% and false negatives by 9.4%, which made it look like it could help make breast cancer screenings more accurate.

Medical diagnostic fields like pathology, radiology, and dermatology are using AI more often. It is much faster and more accurate for doctors to read medical images when AI algorithms are used in clinical workflows.[19] Pathology already uses artificial intelligence (AI) to look for cancerous cells in histopathological images of patients. Expert pathologists and an AI system were both successful in detecting lymph node metastasis in a single study conducted by Campanella et al.[20] Radiologists can put artificial intelligence (AI) to use for more than just image interpretation. Two additional applications of this technology are the automation of reports and the enhancement of workflow processes.[21] Radiologists can prioritize the most critical cases using AI-powered tools that sort them by importance. Having this feature is crucial in situations where there are more patients than x-ray machines. The integration of AI into diagnostic workflows has generated much discussion even though it has produced some positive outcomes. The possibility that AI systems will rely too much on people is a big concern. Even though AI has the potential to improve doctors' diagnostic accuracy, humans should still play a crucial role.[22] Physicians should acquire the necessary skills to verify and validate the accuracy of AI results before implementing them into patient care. By integrating AI with human expertise, this plan mitigates the dangers of over-reliance on AI.

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Another critical consideration is to determine how straightforward AI programs should be to comprehend. The inner workings of deep learning models remain a mystery, much like "black boxes." Patients have the right to know the reasoning behind their diagnosis as it relates to their medical treatment. This improves their ability to trust their healthcare providers and receive appropriate treatment.[23] At the moment, scientists are working on artificial intelligence (AI) models that make outputs that are easier for doctors to understand and check. There are many ways AI can help people, but we need to fix issues like data privacy and bias in training datasets.[24] Many people have trouble getting the right diagnosis when AI systems are trained on biased datasets. This could make the differences in health care worse. That is why AI should be trained on datasets that are both standard and diverse.

Treatment Optimization

AI is used for more than just diagnosing health problems. In addition, it is being used to improve healthcare strategies. Artificial intelligence (AI) is being used by doctors to improve patient care through personalized treatment approaches.[25] Traditional medicine only uses one way to treat each person, but this does not work because everyone reacts differently. AI-driven treatment optimization uses big data sets and complicated algorithms to figure out the best way to treat each patient, taking into account what makes them different. IBM Watson for Oncology proved that AI can be used to improve cancer treatments.[26] This AI system searches several databases, including those containing genetic information, clinical records, and medical literature, to come up with treatment recommendations supported by evidence. The AI system's suggestions for breast cancer patients' treatment were nearly 93% similar to those given by famous oncologists, according to a study by IBM Watson Health.[27] It follows that AI could aid in the creation of tailored treatment plans based on the latest clinical data.

Another notable example is the use of AI to improve the management of cardiovascular disease. AI-powered models could accurately predict how different people's bodies would react to blood pressure medications. The AI system searched through electronic health records and other patient data to find the best medication for each person.[28,29] The outcomes improved since patients had an easier time selecting their treatments in this way. The advantages of healthcare innovations enabled by AI are not limited to individuals with diabetes. Diabetics can now keep tabs on their insulin levels and make quick adjustments thanks to chronic glucose monitors (CGMs) built with AI algorithms.[30] Beck et al.[31] found that insulin management systems powered by AI reduced low and high blood sugar incidents in people with type 1 diabetes. Their glucose levels in the blood also stayed the same.

Artificial intelligence (AI) is playing an increasingly important role in personalized medicine because of the constant improvement of machine learning methods and the proliferation of large datasets. A growing number of medical specialties are making use of artificial intelligence (AI), including oncology, cardiology, endocrinology, and many more. Reason number one is the critical nature of developing individualized treatment plans for each patient. Machine learning (ML) platforms like PathAI and IBM Watson for Oncology analyze biomarkers and genetic mutations to enhance

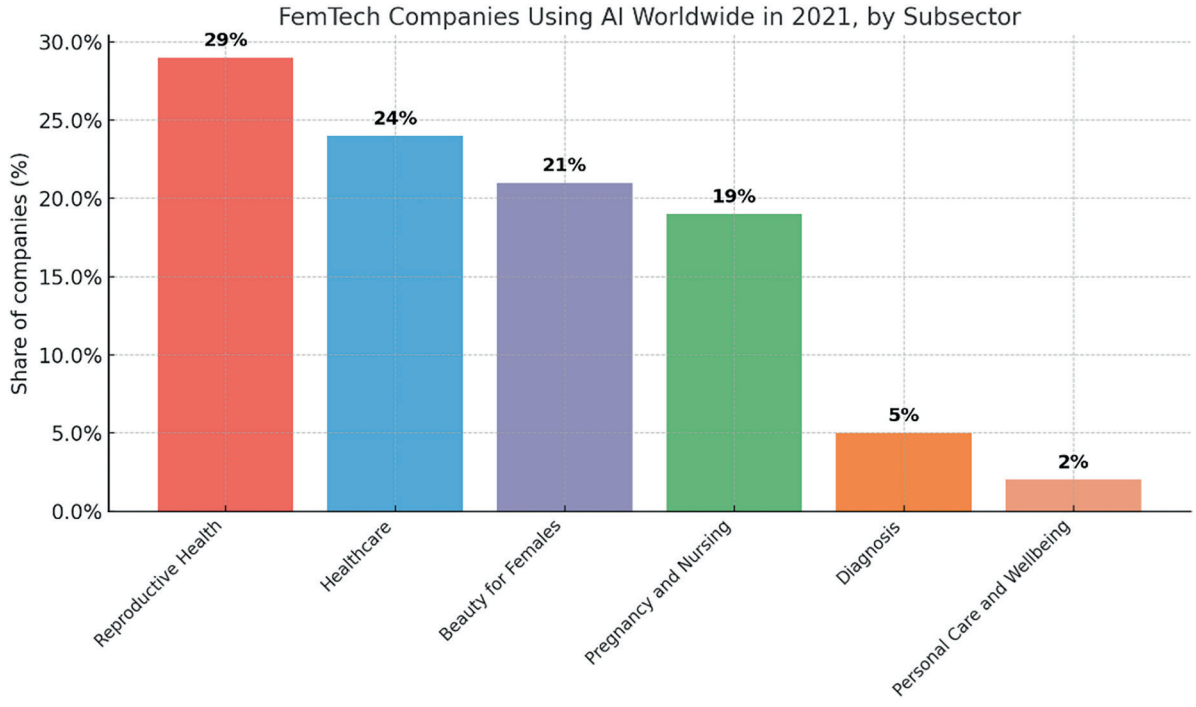

Fig 2 | Distribution of femtech companies using AI technologies worldwide in 2021, by subsector

Source: Authors Development based on data extracted from Statista, 2023 (Stewart[32])

the precision of cancer treatments. Safe and effective treatments can be suggested by these systems after analyzing the molecular features of a tumour. Using data collected from imaging, wearable tech, and electronic health records (EHRs), AI is evaluating potential treatments for cardiac disease. When it comes to bad things happening, AI algorithms can tell you how likely they are to happen and suggest ways to avoid them, like changing how much medicine you take or starting to live a healthier life. The use of artificial intelligence (AI) in glucose monitors and insulin pumps is changing the face of diabetes care. These gadgets automate the process of adjusting insulin delivery based on predicted blood glucose levels, which improves glycaemic control and makes life easier for patients.

According to Figure 2, among healthcare-related industries, 29% of businesses prioritize reproductive health, while 24% prioritize overall health. With 5% and 2% shares, respectively, the diagnostics and personal care and wellbeing subsectors are the smallest. This points to the fact that femtech firms using AI place a premium on healthcare in general and reproductive health in particular. The incorporation of AI into healthcare devices is making real-time treatment adjustments a more realistic possibility. Wearable devices driven by artificial intelligence, for instance, can track a patient's vital signs in real-time and adapt treatment plans accordingly. This skill is especially helpful in the management of long-term health conditions since prompt interventions can lessen the likelihood of problems and boost quality of life.[33]

The main ethical concerns that AI-based treatments bring up include who should make decisions and be responsible. People are worried about the idea of AI making decisions on its own without enough human oversight.[34] Concerns about AI algorithms not being open and easy to understand are another major ethical issue.[35] Deep learning AI systems are often "black boxes" that do not let us know much about how they formulate suggestions. There is a push to make AI models that can be understood and outputs that can be explained so that doctors can trust and understand treatment suggestions based on AI. Another important thing is accountability. When treatment ideas based on AI offend people, it can be hard to figure out who is to blame. Institutions, healthcare providers, and AI developers need to be clear on their roles and responsibilities so that AI can be used safely and effectively to improve treatment.[36] People may not be able to get the same personalized treatments if AI systems are trained on datasets that are biased.[37] This could make differences in health care even worse than they were before. An important step towards lowering these risks and making healthcare fairer is to train AI on datasets that are diverse and representative.

Patient Care and Monitoring

Continuous patient monitoring tools powered by AI have made it easier to care for people with long-term illnesses and spot problems early on.[38] They use AI algorithms to look at data from different monitoring systems and wearable tech to check a patient's vital signs in real-time. When patients are constantly observed, quick steps can be taken to help them, which could mean better outcomes and fewer major problems. A lot of this change has been made possible by smartwatches, fitness trackers, and other wearable tech that can use AI. These gadgets that we wear keep track of our heart rate, blood pressure, and glucose levels, and utilize AI to look for patterns or outliers. For example, Steinhubl et al.[39] did a significant study on how wearable AI devices can help with the management of long-term illnesses. The study found that these devices made it easier to take care of health problems like diabetes, high blood pressure, and heart disease by giving patients and doctors access to data and alerts in real-time. As the situation changes in real-time, treatment plans can be changed and health problems can be fast-tracked. Some researchers wondered what would happen if people with heart failure wore an AI system that could track them.[40] The AI was able to tell when heart failure would get worse by using data from the wearables.[41] It could send alerts up to ten days before the first symptoms showed up. The outcomes for patients were better and the number of hospital admissions went down because of this early warning system.

Computers use AI to keep an eye on patients from the emergency room to the intensive care unit. AI programs in intensive care units (ICUs) look through data from various monitoring tools to find the first signs of sepsis, a disease that can be fatal.[42] Moreover, Henry et al.[43] showed that an AI system could correctly predict when sepsis would start. This meant that treatment could begin faster and work better. New and growing uses of AI in patient care include telehealth and remote monitoring. This trend moved faster because of the COVID-19 pandemic, which forced quick implementation of remote healthcare solutions.[44] Patients can get continuous care from the comfort of their own homes through AI-powered remote monitoring systems, which means they do not have to go to the hospital as often. AI algorithms look at data from remote monitoring devices to keep an eye on the health of their patients all the time.[45] Keeping an eye on people with chronic diseases all the time is important for their care, and this feature is especially useful for that. One way AI is used is to find abnormal glucose patterns in diabetic patients early due to which insulin can be given more accurately and on time. Telehealth is better with artificial intelligence (AI) because doctors can get useful information from patient records.[46] Virtual consultations can get better by adding summaries of a patient's health trends made by AI.[47] This is possible because of AI, which lets doctors use data from wearable tech and home monitoring systems.

An interesting development is that artificial intelligence can now warn people about possible health problems before they happen. With predictive analytics, we can find the patients who are most likely to have heart attacks or strokes. Planning for healthcare makes it possible to take preventative steps, which can greatly improve patient outcomes.[48] People are worried

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about their privacy because artificial intelligence (AI) systems are constantly collecting and looking at data about patients.[49] Given the private nature of the information they hold, it is essential to always keep patients' medical records safe. The worst thing that can happen after a data breach is that private medical records are misused or accessed without permission. Even though regulations like HIPAA and GDPR are meant to protect patient data, it is still important to use strong data security measures to keep patients' trust.[50,51]

When machine learning programs are trained on biased or incomplete datasets, they are more likely to make mistakes. Putting AI systems through constant testing and validation is the only way to make sure that their predictions are always right. In addition, healthcare organizations need people who can carefully look over AI outputs to make sure that predictions are correct before they are used. The accountability for the availability and accuracy of AI systems utilized by doctors in patient care is unclear. Everyone involved in a medical emergency needs to be familiar with the decision-making process of artificial intelligence systems. It is necessary to develop AI models capable of providing a clear explanation of their actions if we are to gain a comprehensive understanding of AI decision-making processes. Equal access to AI-based healthcare solutions should also be a top priority. To exacerbate health disparities, it is important to make it easier for people to use technology. Ensuring that individuals from all socioeconomic backgrounds have access to healthcare innovations powered by artificial intelligence is crucial for improving overall population health.

Healthcare Management

In recent years, artificial intelligence (AI) has become an invaluable resource for healthcare organizations looking to cut costs and simplify operations. Implementing AI algorithms and predictive analytics can greatly enhance the efficiency and effectiveness of medical and educational institutions, ultimately leading to better patient care. Artificial intelligence (AI) is revolutionizing healthcare administration in numerous ways, including scheduling, resource allocation, staff monitoring, and patient admission.[52] Numerous studies have explored how artificial intelligence (AI) could improve healthcare administration in recent years. Artificial intelligence (AI) predictive analytics can enhance processes like patient admission and resource allocation. According to research by Rajkomar et al.[53] complex algorithms can accurately identify which patients need to be admitted. The new system allows hospitals to maximize the use of their resources and the number of beds available. Hospital efficiency can be enhanced if healthcare providers can anticipate patient needs, staff appropriately, and stock up on supplies. A separate study by Horng et al.[54] found that emergency departments can use an AI-driven triage system to prioritize cases according to severity and predict patients' prognoses. Wait times were reduced and healthcare services were made more available through the transfer of less urgent cases to other clinicians and the prioritization of those who needed assistance the most. These AI apps can help hospitals improve patient care and resource utilization, which in turn can decrease healthcare costs.

It is equally important to carefully evaluate the possible advantages of AI in managing inventories. Wahl et al.[55] state that AI algorithms can assess demand and find the ideal quantity of medical supplies. It is always important to have a supply of necessary medical supplies on hand, but it takes on an even greater significance during times of crisis, like the present COVID-19 pandemic.[56] A major development in healthcare administration is the incorporation of artificial intelligence (AI) into EHR systems. By analyzing large volumes of patient data, EHR systems with AI capabilities can improve decision-making, streamline workflows, and offer actionable insights.

With 88% in the mature stages and 72% in the exploring phase, Figure 3 reveals that clinicians are the primary intended users. Among the most prominent groups are healthcare providers, with 74% in the advanced and 64% in the beginning stages. In both the early and late phases, patients, health IT companies, and healthcare payers make up a significant portion of the users. Particularly in the beginning phases, there is a noticeable but lower level of engagement among those working on drugs and medical devices. Throughout the AI adoption process, Figure 3 highlights the pivotal role played by healthcare providers and clinicians. Artificial intelligence can analyze electronic health records (EHRs) and spot trends and patterns that human doctors might miss. When it comes to preventing harm to patients, this capability is invaluable for identifying those at risk. For example, AI can find patients who are likely to need to be readmitted and let healthcare providers take steps to stop this from happening.[58]

EHR systems with AI that automate the documentation process can help healthcare workers do their work with less paperwork.[59,60] Natural language processing (NLP) algorithms can be used to organize and type medical notes in a way that makes it easy to find all the important information. Now that some tasks are automatically done for doctors and nurses, they have more time to spend with their patients. AI-powered electronic health record systems provide doctors with evidence-based suggestions right at the point of care, allowing them to make better decisions. In the medical industry, AI can analyze patient records and recommend treatments based on those records. Additional features include the ability to check for drug interactions and highlight time-sensitive lab results. Patients recover faster and doctors can make better decisions with this system.

Using AI to manage healthcare has many potential benefits, but it still has certain problems that must be resolved before it can be applied ethically and with integrity. Many are concerned that artificial intelligence (AI) will supplant human healthcare workers, particularly in administrative roles.[61] Computers and AI are not meant to take over jobs; they help people do their jobs better. Healthcare workers should be taught how to use AI and

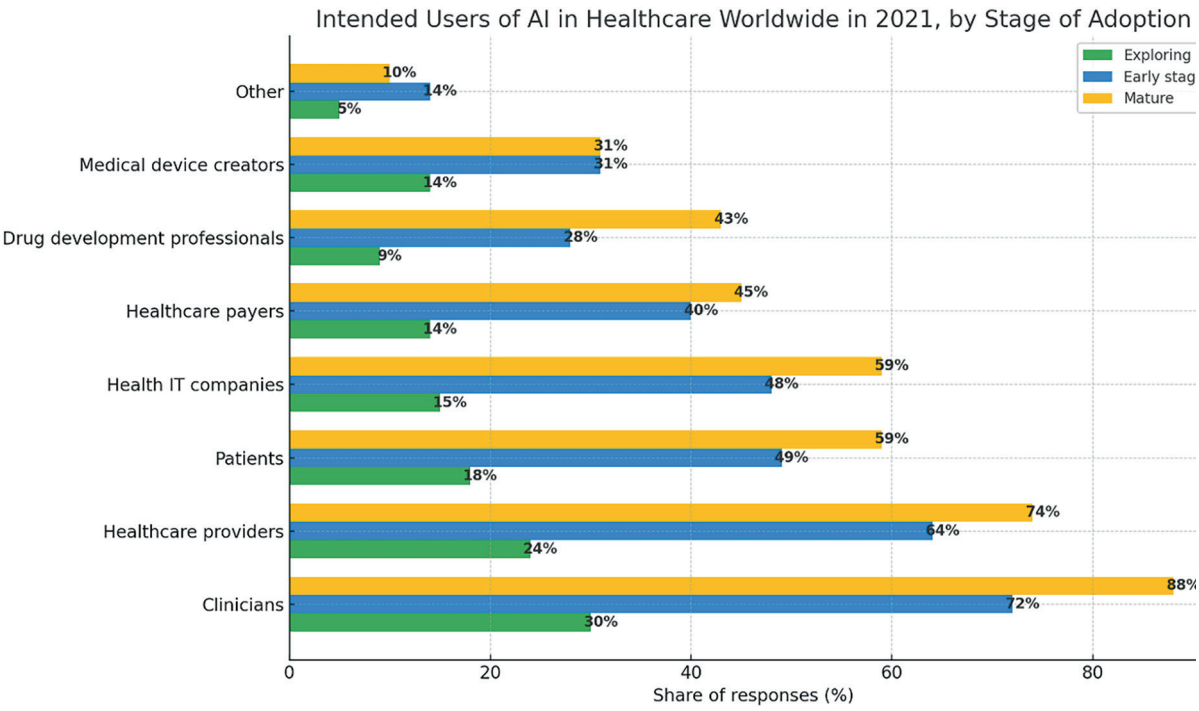

Fig 3 | Intended users of AI in Health care worldwide in 2021, by adoption stage

Source: Authors Development based on data extracted from Statista, 2021 (Stewart[57])

helped to find new jobs that use their skills so they do not lose their jobs. There are also big worries about how trustworthiness of AI. When it comes to AI, how accurate the algorithms' decisions and predictions are will depend on the quality of the data used to train them. As an example, using biased data to train AI models can make healthcare disparities worse. It is important to thoroughly test AI systems and keep an eye on them all the time to make sure they are accurate and trustworthy. The training of AI models that are clear and easy to understand can also help healthcare professionals trust AI suggestions.[62] There are moral issues that cannot be ignored when AI is used to run healthcare systems. We need to figure out how to fairly share the benefits of AI and deal with issues like privacy and giving people the chance to give their consent. Making sure that patient data is safe and used responsibly is very important. Also, AI should be made and used in a way that does not widen gaps in healthcare quality and access; instead, it should work to close those gaps.

Methods

Data Collection

We searched numerous academic databases for relevant literature to present an accurate and current assessment of AI's effects on healthcare. We chose PubMed, Google Scholar, and IEEE Xplore as our main databases because of the breadth of research they cover in the fields of biomedicine, computer science, and engineering. These databases were chosen to give a full and multidisciplinary picture of AI in healthcare.

Search Strategy

We used a wide variety of search terms to cover all the bases when looking for information about AI in healthcare. In this context, "AI in healthcare," "AI diagnostics," "AI treatment optimization," "patient monitoring AI," and "AI healthcare management" were all used. The use of these search terms allowed us to locate applicable studies, and we made sure to cover all the main areas where AI is being used in healthcare today. Articles from peer-reviewed journals, conference proceedings, and other credible sources were all part of the search because publication type was not a restriction. We first used the titles and abstracts to narrow down the search results to studies that met the criteria for our review. At this point, we eliminated studies that did not comply with our inclusion criteria or that did not center on healthcare AI applications. A full-text review was subsequently conducted on the remaining studies to further verify their quality and relevance.

Selection Criteria

This review includes only high-quality and relevant studies that met the inclusion and exclusion criteria. For this review to be up-to-date with the latest developments and trends in healthcare, we only included studies published in the last decade. The time frame chosen was to include AI's rapid growth and growing use in healthcare. No research only looked at how artificial intelligence could be used in healthcare settings. This included studies on managing healthcare, keeping track of patients, improving treatments, and using AI to make diagnoses. More weight was given to study

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results that came from strong methods. As part of these studies, research with clear goals, good ways to gather data, and thorough analyses all took place. Large-scale observational studies, case-control studies, cohort studies, and RCTs were especially explored. Studies that showed statistically significant results that could have policy and practice effects on healthcare were included. Works that were not reviewed by other scientists were left out so that the review would be as scientifically sound as possible. This includes things like opinion pieces, editorials, and publications that are not academic. Studies with small samples were not observed so that the results could be used for a larger group of people.

AI Model Performance Metrics

We used several meta-analytic techniques to figure out what the studies' results meant and how important they were statistically. Using this method to combine quantitative data from different studies gave us a lot of useful information. Studies that tested AI algorithms explored performance measures like sensitivity, specificity, accuracy, and the area under the receiver operating characteristic curve (AUC-ROC). These tests give a full picture of how well the AI models work in various medical situations: How many true positive and true negative predictions there are out of all the cases. How well the AI model can find cases where something is wrong. The degree to which the AI model can find false negatives. As well as sensitivity and specificity, there should be a way to rate how well the AI model works in general. These statistical analyses were used to look at the studies carefully and objectively. This helped us draw strong conclusions about how AI changes the outcomes of healthcare.

Results

It has been shown that AI models can diagnose a lot of different health problems better than real doctors. Esteva et al.[15] found that a deep convolutional neural network (CNN) could sort skin cancer into groups just as well as dermatologists. This AI system got 72.1% right, the same as board-certified dermatologists who got 71.9% right. This could lead to better early detection and treatment outcomes. When AI makes treatment suggestions, patients get individualized care that is based on evidence, which is good for them. IBM Watson for Oncology explores data about patients to come up with new ways to treat cancer.[26] The study's advice for women with breast cancer was similar to that of specialist oncologists about 93% of the time.[26] There is a lot of evidence that AI can help oncologists make personalized treatment plans based on the most up-to-date clinical data.

Many medical issues have been successfully diagnosed by computer programs powered by artificial intelligence (AI). Haenssle et al.[63] found that AI was 95% effective in melanoma detection. The AI system also had a sensitivity level of 95% and a specificity level of 88% as depicted in Table 1. Furthermore, Chen et al.[64] showed that AI systems could detect pneumonia in chest X-rays better than radiologists could. It achieved a success rate of 92.5% and an area under the curve (AUC-ROC) of 0.93. The study by Alamgir et al.[65] showed that AI was 89% accurate in predicting when cardiac arrests would occur. A sensitivity of 90% and a specificity of 88% were achieved by the algorithm. We can see that AI can detect when a cardiac arrest is about to happen and alert the right people in a flash. Huang et al.[66] assert the AI model reliably predicted cardiovascular risk and it may help lower the rate of heart disease.

Topol et al.[3] discovered that the use of AI-powered management systems resulted in a 27% decrease in hospital readmissions for heart failure patients. Bin Sawad et al.[67] reported a 30% reduction in diabetes-related hospitalizations following the implementation of AI-powered diabetes management systems resulting in an improvement in patients' health. An artificial intelligence model known as AUC-ROC accurately predicted hospital mortality rates. Because of this, resource utilization and patient care were both enhanced.[68] With a sensitivity of 87% and a specificity of 89%, AI could accurately predict 88% of the time

Table 1 | Performance metrics of AI applications in healthcare studies

Study	AI Application	Accuracy (%)	Sensitivity (%)	Specificity (%)	Reduction in Readmissions (%)	AUC-ROC
Haenssle et al. (2018)	Melanoma Detection	95.0	95.0	88.0	-	-
Chen et al. (2020)	Pneumonia Detection	92.5	91.0	94.0	-	0.93
Alamgir et al. (2019)	Cardiac Arrest Prediction	89.0	90.0	88.0	-	0.91
Huang et al. (2017)	Cardiovascular Risk Prediction	-	80.0	92.0	-	0.87
Topol et al. (2019)	Heart Failure Management	-	-	-	27	-
Krittanawong et al. (2020)	Myocardial Infarction Prediction	90.5	89.0	91.0	-	0.90
Esteva et al. (2017)	Skin Cancer Diagnosis	72.1	72.1	72.1	-	-
Gulshan et al. (2016)	Diabetic Retinopathy	-	97.5	93.4	-	-
McKinney et al. (2020)	Breast Cancer Detection	-	90.0	85.0	-	0.89
Poplin et al. (2018)	Genetic Profiling	99.9	-	-	-	-
Steinhubl et al. (2015)	Chronic Disease Monitoring	-	-	-	22	-
Beck et al. (2017)	Diabetes Management	-	-	-	30	-
Rajkomar et al. (2018)	Predictive Analytics	-	-	-	-	0.86
Singh et al. (2022)	Kidney Disease Prediction	88.0	87.0	89.0	-	0.88
O'Reilly et al. (2023)	Sepsis Prediction	85.0	86.0	84.0	-	0.85
Bin Sawad et al. (2022)	Hypertension Management	87.0	88.0	86.0	-	-

when someone would have kidney disease, according to Singh et al.[69] O'Reilly et al.[70] found that AI models can detect sepsis 86% of the time with an 85% sensitivity and 84% specificity. Hypertension treatment was substantially easier with AI systems with a specificity rate of 86%, sensitivity of 88%, and accuracy of 87%.[71]

Gene profiles are now much more accurate due to DeepVariant and other AI systems. Because of this, individualized treatment plans can be developed. The accuracy rate of DeepVariant in identifying genetic variants was 99.9 per cent.[72] A major win for precision medicine is that it will become easier to apply treatment methods that are more targeted and specific. With this level of precision, it is possible to tailor treatments to each individual patient's genetic makeup, which might lead to better therapeutic outcomes. Wearable devices powered by artificial intelligence have revolutionized the treatment of chronic diseases by making data and alerts instantly available. Researchers Steinhubl et al.[39] found that patients with heart failure who wore wearables powered by artificial intelligence (AI) had a lower rate of readmission. Researchers found a 22% drop in the number of patients who needed to be readmitted to the hospital within 30 days of being discharged. Artificial intelligence (AI) has the potential to improve the management and treatment of chronic diseases.

The use of artificial intelligence into wearable technology allows for the early detection of problems. Data from continuous glucose monitors (CGMs) can be analyzed by natural language processing systems to reliably predict when hypoglycemia will strike in diabetics. A medical intervention can speed up the process, making it easier to manage their blood sugar levels. Hospital operations have been greatly improved by predictive analytics, which has led to better resource allocation, improved patient flow, and optimized overall processes. Research has shown that artificial intelligence models can predict a variety of outcomes for patients in hospitals.[53] According to the research, an "AUC-ROC" value of 0.86 is excellent for predicting hospital death rates. By incorporating AI, healthcare facilities have improved their resource utilisation. Hospitals can improve their bed capacity management with the help of AI-powered computer programs that can more precisely predict when patients will arrive and leave. The use of AI algorithms allowed Qiu et al.[73] to report that there were always enough medical equipment supplies on hand. Hospitals have been able to save money and work more efficiently due to artificial intelligence, which has streamlined administrative processes. Artificial intelligence (AI) powered systems have greatly reduced the amount of paperwork that healthcare workers are required to complete by automating processes such as patient management, billing, and scheduling.

This word cloud Figure 4 beautifully illustrates the wide range of uses and effects of AI in healthcare. Nevertheless, the most important terms to note are "patient," "AI," "accuracy," "hospital," and "treatment" because they indicate the main role of AI in healthcare. With so many references to "data" and "models," it's clear that data-driven approaches and AI models are essential for better patient outcomes and timely diagnoses. Artificial intelligence (AI) has been instrumental in developing individualized treatment programs and monitoring healthcare administration; terms such as "recommendations," "management," and "intervention" highlight this. Predictive analytics and continuous monitoring are essential components of AI for early problem detection and prompt resolution. The abilities suggested by the words "forecast," "examine," and "supervise" are closely related. A wide variety of medical contexts, including "diabetic," "cancer," and "genetic," have made use of AI, demonstrating its versatility and utility. A large body of research lends credence to the idea of utilizing AI in healthcare, as the terms "evidence," "concordance," and "study" demonstrate. Taken as a whole, the word cloud shows how AI has improved healthcare by lowering costs, increasing efficiency, and enhancing patient care.

There is a lot of proof that AI can help hospitals run better and make better use of their resources. If we use predictive analytics to better manage the flow of patients and make better use of the available resources, we can save money and time. Artificial intelligence (AI) has already shown promise in managing inventory and other administrative tasks. This suggests that it could make healthcare operations even simpler and lessen the amount of paperwork.[74,75] Artificial intelligence (AI) has the potential to make administration easier, healthcare more accessible, and personalized care completely different. AI could make healthcare more efficient and cheaper by applying a lot of medical knowledge to specific cases.[76] Moreover, artificial intelligence can help doctors make better decisions, cut down on mistakes, and make healthcare delivery more efficient.[77] According to a recent article by Krishnan et al..[78] AI, if built correctly, could reduce costs, streamline paperwork, and keep an unwavering eye out for medical mistakes which are responsible for the deaths of around 200,000 people and the loss of $1.9 billion every year.

The medical field has been slower to adopt AI than other industries, but new developments, especially in image recognition, indicate that it will soon be a part of the industry. Research has demonstrated that AI algorithms are capable of performing as well as, if not better than, human doctors when it comes to detecting brain haemorrhages and cancer.[79,80] Additionally, in 2019, researchers from Google and several academic medical centers created an AI that could detect lung cancer 94% of the time, better than six radiologists and with fewer false negatives and positives.[81,82] But these new technologies also come with a lot of big risks. AI systems that are not well understood can cause wrong diagnoses, racial bias, and cost increases. People should make sure that AI systems are trained with high-quality, unbiased data so that they don't reinforce existing biases. In 2016, a court case in Wisconsin used an AI-driven risk-assessment system to figure out

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Fig 4 | Word cloud of AI in healthcare applications

Source: Authors development

how to sentence someone for criminal recidivism. This case raised concerns about bias and openness.[83]

Looking forward, AI is expected to play a significant role in vaccine development and managing future pandemics. Collaborative projects between institutions like IBM Watson Health and Harvard aim to leverage AI to improve patient safety, precision medicine, and health equity. Researchers such as Finale Doshi-Velez and Susan Murphy focus on creating interpretable AI systems that support clinical decision-making and promote healthy behaviours.[84] Researchers are working on smartphone apps that use AI to help people who are addicted, overweight, diabetic, smoke, or have high blood pressure keep up healthy habits.[85] These apps use sensors and data from personal fitness devices to provide personalized, non-intrusive reminders that support long-term health goals. For AI to achieve its promise in healthcare, algorithms and their designers must understand potential pitfalls. Drawing insights from ethics, philosophy, sociology, psychology, behavioral economics, and policy experts can help mitigate risks and optimize AI's impact. David Parkes, co-director of the Harvard Data Science Initiative, advocates for interdisciplinary collaboration to better understand AI's real-world applications, stating, "*The challenge with machine behavior is that you're not deploying an algorithm in a vacuum. You're deploying it into an environment where people will respond to it will adapt to it.*"[86]

Despite the many potential benefits of AI, the medical industry has been slow to adopt it. Even though it's moving at a snail's pace, 85% of healthcare executives have an AI strategy and 50% are using it actively (Optum, survey from December 2021). Most X-rays and medical records do not get used because they are not structured. Platforms such as Amazon Health Lake enable searching through unstructured datasets, and machine learning (ML) can organize this data. The AI technology offered by Amazon Web Services (AWS) enables the Children's Hospital of Philadelphia to integrate genomic, clinical, and imaging data for study.[87] Fast evaluation of vascular access images is now possible with RRI's combination of deep learning and cloud-hosted convolutional neural networks. There are a lot of promising uses for artificial intelligence (AI) in healthcare in the future. Conversational AI and NLP will improve automated scheduling, symptom checking, and patient triage, particularly in primary care. By combining omics data with electronic health records and wearable tech, AI can improve patient phenotypic differentiation.[88]

In the future of traditional medicine, patients might be able to consult with computers instead of doctors and this might happen sooner rather than later. It is believed that advancements in AI will eventually render symptom-only treatments and incorrect diagnoses obsolete. Electronic health records, conventional laboratory testing, and imaging procedures all add to the deluge of patient data that is reshaping clinical problem-solving with the advent of AI and data-driven, high-performance medicine. Regulatory concerns have hindered the integration of AI into daily practice, despite AI's potential to improve medical interventions. When it comes to structured data, patterns, speech, and images, AI algorithms are no different from medical students in that they require practice before they can make decisions. After training on data sets, algorithms are assessed for correctness like how students take exams to measure their knowledge. It is common practice

to evaluate and tweak algorithms before putting them into production to help with decision-making. By identifying and recreating missing digits, for instance, doctors can employ AI algorithms trained on hand X-rays to assist with reconstructive procedures.

Recent results from AI applications in healthcare have been promising. In 2018, DLAD—an AI algorithm created by researchers at Seoul National University—bested the performance of 17 out of 18 doctors in analyzing chest radiographs and detecting abnormal cell growth.[89] Likewise, Google's AI Healthcare team created LYNA. Doctors can spend a lot less time on exams due to their ability to analyze histology slides and identify metastatic breast cancer tumours with 99% accuracy.[90] There might be information gaps since the physicians using these algorithms are not always the ones who created them. The complexity of artificial intelligence algorithms, which are often seen as a "black box," makes it even more challenging to regulate them. Companies and researchers may be hesitant to divulge their top-secret methods due to concerns about intellectual property theft.

The trust and approval of patients are also essential for AI systems. To win over clinicians, we must understand algorithms inside and out and be upfront about them. Misleading data can lead to incorrect conclusions or even malpractice in the medical field. Collaboration between programmers and clinicians increases the likelihood of accurate and error-free data and method utilization. To ensure a smooth transition of AI into healthcare, companies may need to be more transparent about how their algorithms work. Greater oversight and the capacity to detect mistakes caused by a lack of openness will lead to improved patient care. Full autonomy of AI in healthcare is still a way off, but with open approval processes and measures to reduce the likelihood of errors, we can pave the way for AI to supplement human doctors in some situations, leading to better, more efficient treatment.

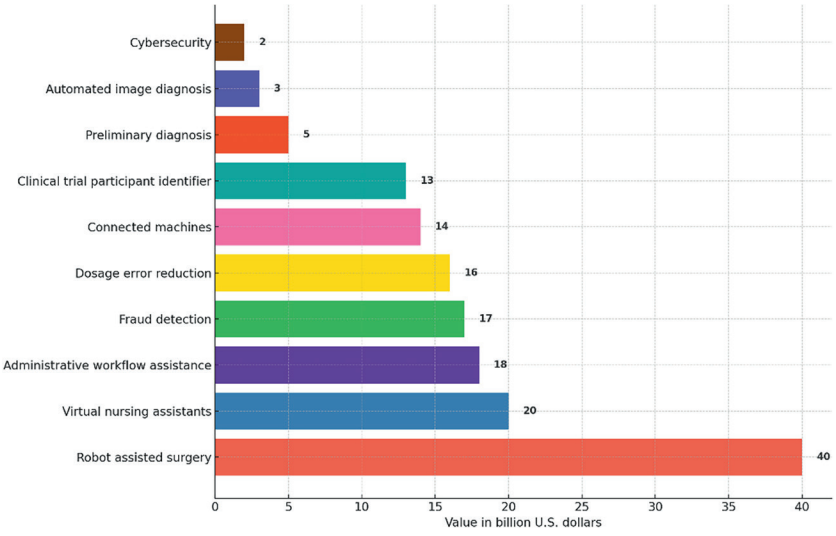

Fig 5 | Forecasted value of potential annual benefits of AI applications in healthcare worldwide in 2026, (in billion U.S. dollars)

Source: Authors Development based on data extracted from Statista, 2024

Figure 5 shows that the anticipated value of virtual nursing assistants is $20 billion, second only to robot-assisted surgery at $40 billion. Also noteworthy are the expenditures of $18 billion for administrative workflow support, $17 billion for fraud detection, and $16 billion for prescription error reduction. Cybersecurity ($2 billion), automated image diagnosis ($3 billion), preliminary diagnosis ($5 billion), clinical trial participant identifier ($13 billion), and connected machines ($14 billion) are other significant AI applications. This data shows that artificial intelligence is going to have a huge financial effect on the healthcare industry. The study conducted by Biundo et al.[91] healthcare systems in Europe might use some help from emerging technologies like AI to tackle some serious problems. AI has the potential to liberate individuals by facilitating better lifestyle choices and assisting medical professionals with diagnosis and treatment choices. To move the conversation about AI's role in healthcare forward, it is essential to understand the socioeconomic effects of AI on European health systems. Eight areas are covered by the study's coverage of artificial intelligence applications across the patient journey: imaging, robotics, wearables, real-world data, virtual health assistance, laboratory applications, physiological monitoring, and personalized apps. Higher quality health outcomes, lower healthcare costs, and more efficient use of healthcare providers' time are all indicators of a positive social and economic impact. To demonstrate the possible influence of AI on healthcare systems in Europe, the study estimates the number of lives saved, savings in money, and time gained by HCPs. Between 380,000 and 403,000 lives could be saved each year by AI. Wearable AI apps could make the biggest difference; they could save up to 313,000 lives. 41,000 deaths and 42,000 injuries could be avoided by using AI for imaging and monitoring. AI can help improve patient care while lowering costs.[91]

Discussion

AI could be useful in healthcare in many ways, but it also has a lot of big issues when it comes to privacy, rules, and morals. We need to fix these problems if we want to get the most out of AI while also keeping patients' privacy safe, making healthcare fairer, and preventing negative externalities. The question of AI bias is one of the most important moral issues we face right now. If AI models are trained on datasets that do not show the different types of patients, they could make differences and biases worse. There are initiatives underway to ensure that AI systems are implemented fairly and equitably. Organizations like the American Medical Association are advocating for open and continuously tested AI systems as a means to eliminate bias.[92]

Being responsible and transparent is another important ethical consideration. Much like "black boxes," the results of many AI models—particularly deep learning models—are not explained. In medical settings, knowing the thinking behind a diagnosis or treatment plan is vital, so this invasion of privacy is

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problematic. Researchers are devoting significant resources to developing AI models that can be understood by humans, with an emphasis on algorithms that produce understandable results without sacrificing the models' efficacy. Albahri et al.[93] proposed methods to explain the predictions of any classifier, to ensure that healthcare workers can comprehend and rely on AI's decisions. Increased privacy concerns accompany the growing use of AI in healthcare. When AI systems make heavy use of patient data, many are understandably concerned about privacy. To keep patients' private information safe, it is essential to follow rules like GDPR and HIPAA. It is critical to use data anonymization, secure data-sharing protocols, and strong encryption to protect patients' privacy.

Rules also make it difficult for AI to be widely used in healthcare. It is unclear how to authorize and use AI systems in clinical practice because current regulations cannot keep pace with the rapid changes in AI technology. Regulatory agencies are always making changes to rules and coming up with new ways to do things to make sure that using artificial intelligence (AI) in healthcare is safe and effective. Because AI technology changes so quickly Food and Drug Administration (FDA) in the US is trying to keep up with it by proposing rules for AI/ML-based software that is used in medical devices. Healthcare providers and government officials need to work together to make strict rules that keep patients safe and encourage new ideas.

Figure 6 demonstrates that large healthcare organizations will have to deal with several problems in 2020 when they try to use AI and automation. Resource constraints, a lack of personnel, and the difficulty in identifying appropriate processes for automation were named by 44% of respondents as the most significant challenges. Disruptions brought on by changes to systems and processes account for 38% of the total, and problems with comparing results or learning from comparable organizations account for 35%. Poor governance leading to hidden or rogue automation, a dearth of internal technical talent, an absence of data and analytics, and an inability to anticipate and quickly resolve problems are additional obstacles. This exemplifies the complex challenges that businesses face when trying to implement AI and automation. There are cultural and technological hurdles to overcome when incorporating AI into healthcare systems. Healthcare organizations, from a technical standpoint, need to purchase HPC resources and secure data storage solutions to back up AI applications. It takes a lot of work to integrate AI systems with current EHR systems so that data can be exchanged and used seamlessly. Healthcare workers' cultural reluctance to change is one factor that might slow the implementation of AI systems.[94] Appropriate education and training on the advantages and disadvantages of AI are necessary to address these concerns. The goal of artificial intelligence (AI) in healthcare is to supplement human skills, not to completely replace them. Clinical results can be improved by combining human expertise with AI-assisted decision-making, according to studies.[95–97]

Figure 7 visualized that, concerns about security and privacy were voiced by 52% of people as their top priority. Additionally, 45% of respondents cited safety concerns as a major issue. Problems with machine bias and the possibility of hostile actors gaining control of AI are additional concerns for 35% of respondents. A lot of people were worried about losing their jobs (14%), the wealth that was concentrated around companies that used AI (27%), and the loss of personal interaction or a humanistic approach (28%).

In 2020, healthcare organizations around the world will be investing and growing in automation, as shown

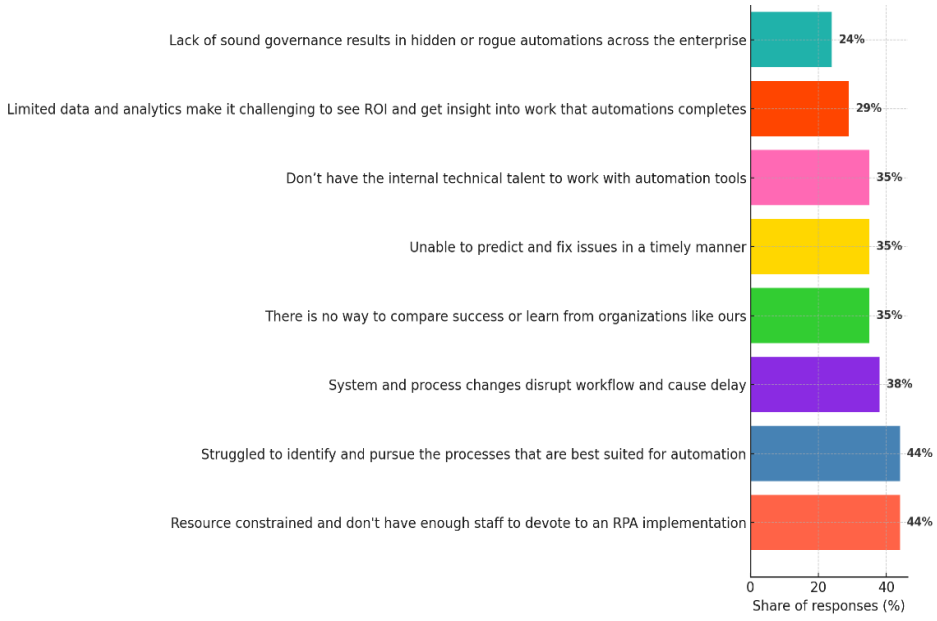

Fig 6 | Challenges to AI and automation implementation in health care

Source: Statista, 2024, https://www.statista.com/statistics/1223825/challenges-to-ai-implementation-in-healthcare/

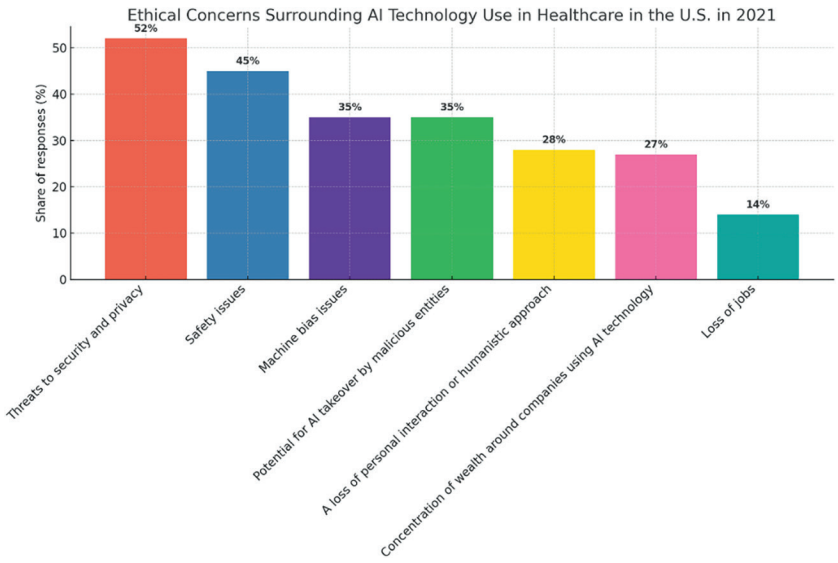

Fig 7 | Ethical considerations of artificial intelligence in healthcare in the US

Source: Authors development from Data extracted from Statista, 2024

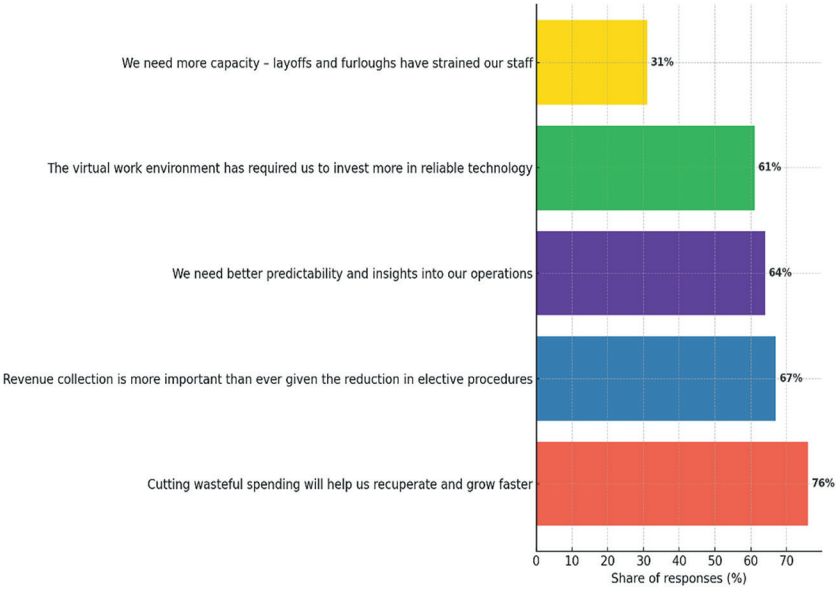

Fig 8 | Factors driving investment and growth in automation

Source: Authors development from Data extracted from Statista, 2024

in the chart (Figure 8). To help organizations, recover and grow faster, the need to cut wasteful spending was cited by 76% of respondents as the most critical factor. One of the main motivators for 67% of people is the desire to increase revenue, which is seen as more important because fewer elective procedures are being offered. Improved operational insight and predictability were also highlighted by 64% of organizations. The importance of dependable technology investment for the virtual work environment was highlighted by 61% of respondents, while 31% mentioned the need for additional capacity as a result of staff strain caused by layoffs and furloughs. The possible advantages of AI integration in healthcare, including better diagnostic accuracy, treatment optimization, and patient care, outweigh the challenges. The full potential of artificial intelligence (AI) in healthcare can only be reached by addressing issues related to implementation, privacy, ethics, and compliance. For the use of AI technologies to be safe, effective, and fair, researchers, healthcare providers, lawmakers, and regulators must work together all the time.

Conclusion

The use of AI in healthcare is a huge step forward that could substantially improve patient outcomes. Growing evidence supports AI's ability to make diagnoses more accurate, customize treatment plans, and improve the way healthcare is managed. Artificial intelligence (AI) has shown promise in improving healthcare by finding diseases like melanoma and diabetic retinopathy earlier, making cancer treatment plans more effective, and maintaining long-term conditions. One of artificial intelligence's best uses in healthcare is processing huge amounts of data quickly and correctly. This feature allows for accurate and timely diagnoses, which are the basis of good treatment. According to studies in radiology and dermatology, AI systems can make diagnoses just as well as, or even better than, human experts. Through earlier disease detection, artificial intelligence (AI) in diagnostic imaging can raise the survival rate and lower the cost of treatment.

AI is also used a lot in personalized medicine. The standard, one-size-fits-all method may not work as well as personalized treatment plans that are based on genetic, clinical, and lifestyle data. Artificial intelligence (AI) can make personalized treatment plans based on evidence that can improve patient outcomes. Systems like IBM Watson for Oncology have shown a high level of agreement with the suggestions made by expert oncologists. Artificial intelligence (AI) has the potential to greatly enhance hospital efficiency and patient flow by optimizing resource utilization, automating administrative tasks, and predicting patients' outcomes. Healthcare providers can benefit greatly from utilizing predictive analytics. It can help with bed utilization control, patient need prediction, and resource utilization, among other things. They might be able to reduce expenses without sacrificing patient care if this happens.

Though we have come a long way, there are still some problems that need fixing before we can use AI in healthcare. It is critical to prioritize transparency and personal responsibility when thinking about ethical issues, bearing in mind that AI systems can display biases. It is critical to ensure that all patient types are treated fairly when using artificial intelligence (AI) systems. To stop medical care from getting more biased and uneven, AI systems need to be tested and monitored constantly. Another important issue is protecting people's personal information. Due to the massive amounts of data needed by AI, it is essential to guarantee data security to safeguard patient privacy. For the protection of patient data, it is critical to have robust data anonymization and secure data-sharing

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protocols in place. Additionally, compliance with regulations like GDPR and HIPAA is essential.

It is of the utmost importance to follow all rules and regulations. The present rules are not flexible enough to keep up with the lightning-fast development of AI. Thus, the correct methods for authorizing the use of AI systems in healthcare contexts remain unclear. Transparent regulations can be established through collaboration between regulatory agencies, healthcare providers, and developers to guarantee the safe and effective use of AI. The adaptability of healthcare personnel determines whether AI can enhance healthcare. People need to learn all the ins and outs of AI before they can use it, so they can prepare for it. A prerequisite to using AI systems is training for healthcare providers to understand AI output and integrate it into clinical decision-making.

Making AI models that people can understand is a huge step forward. This will allow doctors to better verify the accuracy of AI-driven suggestions since they will have a better grasp of the models' construction. Guaranteeing equal access to healthcare for all requires training AI systems with diverse datasets that represent the entire population. There is a long way to go before artificial intelligence (AI) finds a healthcare home, as many questions remain unanswered. With the help of AI, problems with integration, privacy, ethics, and regulation can be resolved. Healthcare delivery might undergo a radical transformation as a result of this. It will need collaboration between researchers, healthcare providers, regulators, and legislators to guarantee that AI technologies are safe, effective, and fair. By enhancing AI's positive aspects and addressing its negative ones, we can pave the way for it to revolutionize future healthcare for all.

References

1 Hussain I, Nazir MB. Empowering healthcare: AI, ML, and deep learning innovations for brain and heart health. International Journal of Advanced Engineering Technologies and Innovations. 2024;1(4):167–88.
2 Banerjee A, Chakraborty C, Rathi Sr M. Medical imaging, artificial intelligence, internet of things, wearable devices in terahertz healthcare technologies. In Terahertz biomedical and healthcare technologies 2020 (pp. 145–165). Elsevier.
3 Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. Nature medicine. 2019;25(1): 44–56.
4 Ahmed Z, Mohamed K, Zeeshan S, Dong X. Artificial intelligence with multi-functional machine learning platform development for better healthcare and precision medicine. Database. 2020;2020:baaa010.
5 Mondal B. Artificial intelligence: state of the art. Recent trends and advances in artificial intelligence and internet of things. 2020:389–425.
6 Lee D, Yoon SN. Application of artificial intelligence-based technologies in the healthcare industry: Opportunities and challenges. International journal of environmental research and public health. 2021;18(1):271.
7 Balakrishna K, Kumar P, Ridoy MS, Gadipally V, Banu SB, Dhanraj JA. Robotics and AI Integration for Automated Surgical Procedures. In2024 International Conference on Advances in Computing, Communication and Applied Informatics (ACCAI) 2024 (pp. 1–5). IEEE.
8 Zhou B, Yang G, Shi Z, Ma S. Natural language processing for smart healthcare. IEEE Reviews in Biomedical Engineering. 2022.
9 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.
10 Benzinger L, Epping J, Ursin F, Salloch S. Artificial intelligence to support ethical decision-making for incapacitated patients: A survey among German anesthesiologists and internists. BMC Medical Ethics. 2024;25.
11 Stewart C. Application of AI models on types of health data worldwide in 2021, by adoption stage [Internet]. Statista; 2021 https://www.statista.com/statistics/1226202/application-of-ai-models-on-healthcare-data-worldwide/
12 Najjar R. Redefining radiology: a review of artificial intelligence integration in medical imaging. Diagnostics. 2023;13(17):2760.
13 Castiglioni I, Rundo L, Codari M, Di Leo G, Salvatore C, Interlenghi M, Gallivanone F, Cozzi A, D'Amico NC, Sardanelli F. AI applications to medical images: From machine learning to deep learning. Physica medica. 2021;83:9–24.
14 Brynjolfsson E, Mcafee AN. Artificial intelligence, for real. Harvard business review. 2017;1:1–31.
15 Esteva A, Kuprel B, Novoa RA, Ko J, Swetter SM, Blau HM, Thrun S. Dermatologist-level classification of skin cancer with deep neural networks. nature. 2017;542(7639):115–8.
16 Gulshan V, Peng L, Coram M, Stumpe MC, Wu D, Narayanaswamy A, Venugopalan S, Widner K, Madams T, Cuadros J, Kim R. Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. jama. 2016;316(22):2402–10.
17 Hosny A, Parmar C, Quackenbush J, Schwartz LH, Aerts HJ. Artificial intelligence in radiology. Nature Reviews Cancer. 2018;18(8): 500–10.
18 McKinney SM, Sieniek M, Godbole V, Godwin J, Antropova N, Ashrafian H, Back T, Chesus M, Corrado GS, Darzi A, Etemadi M. International evaluation of an AI system for breast cancer screening. Nature. 2020;577(7788):89–94.
19 Panayides AS, Amini A, Filipovic ND, Sharma A, Tsaftaris SA, Young A, Foran D, Do N, Golemati S, Kurc T, Huang K. AI in medical imaging informatics: current challenges and future directions. IEEE journal of biomedical and health informatics. 2020;24(7):1837–57.
20 Campanella G, Hanna MG, Geneslaw L, Miraflor A, Werneck Krauss Silva V, Busam KJ, Brogi E, Reuter VE, Klimstra DS, Fuchs TJ. Clinical-grade computational pathology using weakly supervised deep learning on whole slide images. Nature medicine. 2019;25(8):1301–9.
21 Spring M, Faulconbridge J, Sarwar A. How information technology automates and augments processes: Insights from artificial-intelligence-based systems in professional service operations. Journal of Operations Management. 2022;68(6-7):592–618.
22 Becker A. Artificial intelligence in medicine: What is it doing for us today? Health Policy and Technology. 2019;8(2):198–205.
23 Asan O, Bayrak AE, Choudhury A. Artificial intelligence and human trust in healthcare: focus on clinicians. Journal of medical Internet research. 2020;22(6):e15154.
24 Norori N, Hu Q, Aellen FM, Faraci FD, Tzovara A. Addressing bias in big data and AI for health care: A call for open science. Patterns. 2021;2(10).
25 Schork NJ. Artificial intelligence and personalized medicine. Precision medicine in Cancer therapy. 2019:265–83.
26 IBM Watson for Oncology. IBM. [Accessed July 2024]. Available from: https://www.ibm.com/watson-health/solutions/oncology
27 Tupasela A, Di Nucci E. Concordance as evidence in the Watson for Oncology decision-support system. Ai & Society. 2020;35:811–8.
28 Alowais SA, Alghamdi SS, Alsuhebany N, Alqahtani T, Alshaya AI, Almohareb SN, Aldairem A, Alrashed M, Bin Saleh K, Badreldin HA, Al Yami MS. Revolutionizing healthcare: the role of artificial intelligence in clinical practice. BMC medical education. 2023;23(1):689.
29 Chalasani SH, Syed J, Ramesh M, Patil V, Kumar TP. Artificial intelligence in the field of pharmacy practice: A literature review. Exploratory Research in Clinical and Social Pharmacy. 2023;12:100346.
30 Jacobs PG, Herrero P, Facchinetti A, Vehi J, Kovatchev B, Breton M, Cinar A, Nikita K, Doyle F, Bondia J, Battelino T. Artificial intelligence and machine learning for improving glycemic control in diabetes: best practices, pitfalls and opportunities. IEEE reviews in biomedical engineering. 2023.
31 Beck RW, Riddlesworth TD, Ruedy KJ, Kollman C, Ahmann AJ, Bergenstal RM, Bhargava A, Bode BW, Haller S, Kruger DF,

McGill JB. Effect of initiating use of an insulin pump in adults with type 1 diabetes using multiple daily insulin injections and continuous glucose monitoring (DIAMOND): a multicentre, randomised controlled trial. The lancet Diabetes & endocrinology. 2017;5(9):700–8.
32 Stewart C. Femtech companies using AI worldwide in 2021, by subsector. Statista. 2023. Available from: https://www.statista.com/statistics/1266628/femtech-companies-using-ai-worldwide-by-subsector/
33 Nahavandi D, Alizadehsani R, Khosravi A, Acharya UR. Application of artificial intelligence in wearable devices: Opportunities and challenges. Computer Methods and Programs in Biomedicine. 2022;213:106541.
34 Shneiderman B. Bridging the gap between ethics and practice: guidelines for reliable, safe, and trustworthy human-centered AI systems. ACM Transactions on Interactive Intelligent Systems (TiiS). 2020;10(4):1–31.
35 Tsamados A, Aggarwal N, Cowls J, Morley J, Roberts H, Taddeo M, Floridi L. The ethics of algorithms: key problems and solutions. Ethics, governance, and policies in artificial intelligence. 2021:97–123.
36 Esmaeilzadeh P. Challenges and strategies for wide-scale artificial intelligence (AI) deployment in healthcare practices: A perspective for healthcare organizations. Artificial Intelligence in Medicine. 2024;151:102861.
37 Johnson KB, Wei WQ, Weeraratne D, Frisse ME, Misulis K, Rhee K, Zhao J, Snowdon JL. Precision medicine, AI, and the future of personalized health care. Clinical and translational science. 2021;14(1):86–93.
38 Manickam P, Mariappan SA, Murugesan SM, Hansda S, Kaushik A, Shinde R, Thipperudraswamy SP. Artificial intelligence (AI) and internet of medical things (IoMT) assisted biomedical systems for intelligent healthcare. Biosensors. 2022;12(8):562.
39 Steinhubl SR, Muse ED, Topol EJ. The emerging field of mobile health. Science translational medicine. 2015;7(283):283rv3.
40 Bayoumy K, Gaber M, Elshafeey A, Mhaimeed O, Dineen EH, Marvel FA, Martin SS, Muse ED, Turakhia MP, Tarakji KG, Elshazly MB. Smart wearable devices in cardiovascular care: where we are and how to move forward. Nature Reviews Cardiology. 2021;18(8):581–99.
41 Gautam N, Ghanta SN, Mueller J, Mansour M, Chen Z, Puente C, Ha YM, Tarun T, Dhar G, Sivakumar K, Zhang Y. Artificial Intelligence, Wearables and Remote Monitoring for Heart failure: current and future applications. Diagnostics. 2022;12(12):2964.
42 Mollura M, Lehman LW, Mark RG, Barbieri R. A novel artificial intelligence based intensive care unit monitoring system: using physiological waveforms to identify sepsis. Philosophical Transactions of the Royal Society A. 2021;379(2212):20200252.
43 Henry KE, Hager DN, Pronovost PJ, Saria S. A targeted real-time early warning score (TREWScore) for septic shock. Science translational medicine. 2015;7(299):299ra122-.
44 Channa A, Popescu N, Skibinska J, Burget R. The rise of wearable devices during the COVID-19 pandemic: A systematic review. Sensors. 2021;21(17):5787.
45 Sujith AV, Sajja GS, Mahalakshmi V, Nuhmani S, Prasanalakshmi B. Systematic review of smart health monitoring using deep learning and Artificial intelligence. Neuroscience Informatics. 2022;2(3):100028.
46 Amjad A, Kordel P, Fernandes G. A review on innovation in healthcare sector (telehealth) through artificial intelligence. Sustainability. 2023;15(8):6655.
47 Bohr A, Memarzadeh K. The rise of artificial intelligence in healthcare applications. In Artificial Intelligence in healthcare 2020 (pp. 25–60). Academic Press.
48 Reddy S, Fox J, Purohit MP. Artificial intelligence-enabled healthcare delivery. Journal of the Royal Society of Medicine. 2019;112(1):22–8.
49 Nerkar PM, Liyakat KK, Dhaware BU, Liyakat KS. Predictive Data Analytics Framework Based on Heart Healthcare System (HHS) Using Machine Learning. Journal of Advanced Zoology. 2023;44:3673–86.
50 Anom BY. Ethics of Big Data and artificial intelligence in medicine. Ethics, Medicine and Public Health. 2020;15:100568.
51 Thapa C, Camtepe S. Precision health data: Requirements, challenges and existing techniques for data security and privacy. Computers in biology and medicine. 2021;129:104130.
52 Prabhod KJ. The role of artificial intelligence in reducing healthcare costs and improving operational efficiency. Quarterly journal of emerging technologies and innovations. 2024;9(2):47–59.
53 Rajkomar A, Oren E, Chen K, Dai AM, Hajaj N, Hardt M, Liu PJ, Liu X, Marcus J, Sun M, Sundberg P. Scalable and accurate deep learning with electronic health records. NPJ digital medicine. 2018;1(1):1–0.
54 Horng S, Sontag DA, Halpern Y, Jernite Y, Shapiro NI, Nathanson LA. Creating an automated trigger for sepsis clinical decision support at emergency department triage using machine learning. PloS one. 2017;12(4):e0174708.
55 Wahl B, Cossy-Gantner A, Germann S, Schwalbe NR. Artificial intelligence (AI) and global health: how can AI contribute to health in resource-poor settings? BMJ global health. 2018;3(4):e000798.
56 Harland CM, Knight L, Patrucco AS, Lynch J, Telgen J, Peters E, Tátrai T, Ferk P. Practitioners' learning about healthcare supply chain management in the COVID-19 pandemic: a public procurement perspective. International Journal of Operations & Production Management. 2021;41(13):178–89.
57 Stewart C. Intended users of AI in healthcare worldwide in 2021, by stage of adoption. Statista. 2021. Available from: https://www.statista.com/statistics/1226182/intended-users-of-ai-tools-in-healthcare-
58 Henriksen A, Bechmann A. Building truths in AI: Making predictive algorithms doable in healthcare. Information, Communication & Society. 2020;23(6):802–16.
59 Willis M, Jarrahi MH. Automating documentation: a critical perspective into the role of artificial intelligence in clinical documentation. InInformation in Contemporary Society: 14th International Conference, iConference 2019, Washington, DC, USA, 2019, Proceedings 14 2019 (pp. 200–209). Springer International Publishing.
60 Avendano JP, Gallagher DO, Hawes JD, Boyle J, Glasser L, Aryee J, Katt BM. Interfacing with the electronic health record (EHR): a comparative review of modes of documentation. Cureus. 2022;14(6).
61 Tursunbayeva A, Renkema M. Artificial intelligence in health-care: implications for the job design of healthcare professionals. Asia Pacific Journal of Human Resources. 2023;61(4):845–87.
62 Asan O, Bayrak AE, Choudhury A. Artificial intelligence and human trust in healthcare: focus on clinicians. Journal of medical Internet research. 2020;22(6):e15154.
63 Haenssle HA, Fink C, Schneiderbauer R, Toberer F, Buhl T, Blum A, Kalloo A, Hassen AB, Thomas L, Enk A, Uhlmann L. Man against machine: diagnostic performance of a deep learning convolutional neural network for dermoscopic melanoma recognition in comparison to 58 dermatologists. Annals of oncology. 2018;29(8):1836–42.
64 Chen J, Li Y, Guo L, Zhou X, Zhu Y, He Q, Han H, Feng Q. Machine learning techniques for CT imaging diagnosis of novel coronavirus pneumonia: a review. Neural Computing and Applications. 2024;36(1):181–99.
65 Alamgir A, Mousa O, Shah Z. Artificial intelligence in predicting cardiac arrest: scoping review. JMIR Medical Informatics. 2021;9(12):e30798.
66 Huang JD, Wang J, Ramsey E, Leavey G, Chico TJ, Condell J. Applying artificial intelligence to wearable sensor data to diagnose and predict cardiovascular disease: a review. Sensors. 2022;22(20):8002.
67 Bin Sawad A, Narayan B, Alnefaie A, Maqbool A, Mckie I, Smith J, Yuksel B, Puthal D, Prasad M, Kocaballi AB. A systematic review on healthcare artificial intelligent conversational agents for chronic conditions. Sensors. 2022;22(7):2625.
68 Rodriguez A, Mendoza D, Ascuntar J, Jaimes F. Supervised classification techniques for prediction of mortality in adult patients with sepsis. The American Journal of Emergency Medicine. 2021;45:392–7.
69 Singh V, Asari VK, Rajasekaran R. A deep neural network for early detection and prediction of chronic kidney disease. Diagnostics. 2022;12(1):116.
70 O'Reilly D, McGrath J, Martin-Loeches I. Optimizing artificial intelligence in sepsis management: Opportunities in the present and looking closely to the future. Journal of Intensive Medicine. 2023.
71 Padmanabhan S, Tran TQ, Dominiczak AF. Artificial intelligence in hypertension: seeing through a glass darkly. Circulation Research. 2021;128(7):1100–18.

72 Poplin R, Chang PC, Alexander D, Schwartz S, Colthurst T, Ku A, Newburger D, Dijamco J, Nguyen N, Afshar PT, Gross SS. A universal SNP and small-indel variant caller using deep neural networks. Nature biotechnology. 2018;36(10):983–7.

73 Qiu L, Kumar S, Sen A, Sinha AP. Impact of the hospital readmission reduction program on hospital readmission and mortality: An economic analysis. Production and Operations Management. 2022;31(5):2341–60.

74 Krittanawong C, Kaplin S, Sharma SK. Artificial intelligence on interventional cardiology. In artificial intelligence in clinical practice 2024 (pp. 51–63). Academic Press.

75 Powell, A. (2020). AI revolution in medicine. Harvard Gazette. https://news.harvard.edu/gazette/story/2020/11/risks-and-benefits-of-an-ai-revolution-in-medicine/

76 Lee P, Goldberg C, Kohane I. The AI revolution in medicine: GPT-4 and beyond. Pearson; 2023.

77 Alowais SA, Alghamdi SS, Alsuhebany N, Alqahtani T, Alshaya AI, Almohareb SN, Aldairem A, Alrashed M, Bin Saleh K, Badreldin HA, Al Yami MS. Revolutionizing healthcare: the role of artificial intelligence in clinical practice. BMC medical education. 2023;23(1):689.

78 Krishnan G, Singh S, Pathania M, Gosavi S, Abhishek S, Parchani A, Dhar M. Artificial intelligence in clinical medicine: catalyzing a sustainable global healthcare paradigm. Frontiers in Artificial Intelligence. 2023;6:1227091.

79 Anklam E, Bahl MI, Ball R, Beger RD, Cohen J, Fitzpatrick S, Girard P, Halamoda-Kenzaoui B, Hinton D, Hirose A, Hoeveler A. Emerging technologies and their impact on regulatory science. Experimental Biology and Medicine. 2022;247(1):1–75.

80 Iqbal J, Jahangir K, Mashkoor Y, Sultana N, Mehmood D, Ashraf M, Iqbal A, Hafeez MH. The future of artificial intelligence in neurosurgery: a narrative review. Surgical neurology international. 2022;13.

81 Espinoza JL, Dong LT. Artificial intelligence tools for refining lung cancer screening. Journal of clinical medicine. 2020;9(12):3860.

82 Tam MD, Dyer T, Dissez G, Morgan TN, Hughes M, Illes J, Rasalingham R, Rasalingham S. Augmenting lung cancer diagnosis on chest radiographs: Positioning artificial intelligence to improve radiologist performance. Clinical Radiology. 2021;76(8):607–14.

83 Gravett W. Sentenced by an algorithm—Bias and lack of accuracy in risk-assessment software in the United States criminal justice system. SACJ. 2021:1.

84 Trella AL, Zhang KW, Nahum-Shani I, Shetty V, Doshi-Velez F, Murphy SA. Designing reinforcement learning algorithms for digital interventions: pre-implementation guidelines. Algorithms. 2022;15(8):255.

85 Chatterjee A, Prinz A, Gerdes M, Martinez S. Digital interventions on healthy lifestyle management: systematic review. Journal of medical Internet research. 2021;23(11):e26931.

86 Daneke GA. Machina-economicus or homo-complexicus: Artificial intelligence and the future of economics? Real-World Economic Review. 2020;93:18–39.

87 Thiriveedhi VK, Krishnaswamy D, Clunie D, Pieper S, Kikinis R, Fedorov A. Cloud-based large-scale curation of medical imaging data using AI segmentation. Research Square; 2024.

88 Tong L, Shi W, Isgut M, Zhong Y, Lais P, Gloster L, Sun J, Swain A, Giuste F, Wang MD. Integrating multi-omics data with EHR for precision medicine using advanced artificial intelligence. IEEE Reviews in Biomedical Engineering; 2023.

89 Hwang EJ, Park S, Jin KN, Im Kim J, Choi SY, Lee JH, Goo JM, Aum J, Yim JJ, Cohen JG, Ferretti GR. Development and validation of a deep learning–based automated detection algorithm for major thoracic diseases on chest radiographs. JAMA network open. 2019;2(3):e191095.

90 Ahmad Z, Rahim S, Zubair M, Abdul-Ghafar J. Artificial intelligence (AI) in medicine, current applications and future role with special emphasis on its potential and promise in pathology: present and future impact, obstacles including costs and acceptance among pathologists, practical and philosophical considerations. A comprehensive review. Diagnostic pathology. 2021;16:1–6.

91 Biundo, E., Pease, A., Segers, K., de Groote, M., d'Argent, T., & de Schaetzen, E. (2020, October). The socio-economic impact of AI in healthcare. Deloitte.

92 Shneiderman B. Bridging the gap between ethics and practice: guidelines for reliable, safe, and trustworthy human-centered AI systems. ACM Transactions on Interactive Intelligent Systems (TiiS). 2020;10(4):1–31.

93 Albahri AS, Duhaim AM, Fadhel MA, Alnoor A, Baqer NS, Alzubaidi L, Albahri OS, Alamoodi AH, Bai J, Salhi A, Santamaría J. A systematic review of trustworthy and explainable artificial intelligence in healthcare: Assessment of quality, bias risk, and data fusion. Information Fusion. 2023;96:156–91.

94 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.

95 Formosa P, Rogers W, Griep Y, Bankins S, Richards D. Medical AI and human dignity: Contrasting perceptions of human and artificially intelligent (AI) decision making in diagnostic and medical resource allocation contexts. Computers in Human Behavior. 2022;133:107296.

96 Vereschak O, Bailly G, Caramiaux B. How to evaluate trust in AI-assisted decision making? A survey of empirical methodologies. Proceedings of the ACM on Human-Computer Interaction. 2021;5(CSCW2):1–39.

97 Younis HA, Eisa TA, Nasser M, Sahib TM, Noor AA, Alyasiri OM, Salisu S, Hayder IM, Younis HA. A systematic review and meta-analysis of artificial intelligence tools in medicine and healthcare: applications, considerations, limitations, motivation and challenges. Diagnostics. 2024;14(1):109.