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Artificial Intelligence in public health: A case study

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Abstract

Artificial Intelligence technology has become an innovative tool in global healthcare that helps to manage various problems of scale and complexity. Its use in public health is multifaceted and multivariate extending across early outbreak detection, risk modeling and prediction, efficient vaccine logistics and administration, reducing health disparities, aiding assist in diagnosis, everyday monitoring of chronic diseases, telemedicine and virtual chatbots especially for elderly care, mental health and oncology patients, and community engagement. Despite these huge generational advantages, multiple challenges exist in data quality, security and misuse, individual privacy, contextual application, accountability and oversight and remain primary concerns for universal adoption of artificial intelligence. There is a need for safeguards and a global regulatory framework to responsibly harvest the benefits of artificial intelligence for the advancement of public and community health.

Keywords: Artificial Intelligence; Health; Diagnosis; Monitoring; Medicine; Data; COVID-19; Cancer; Outbreak; Personalized Medicine; Precision Medicine

1. Introduction

Artificial Intelligence (AI) is a promising tool in healthcare since it is capable of analyzing a huge amount of information, identifying trends or patterns and providing instant feedback on simple or complex problems as well as integrate into the big-picture notion of health for the population, and enhance population health and health systems [1]. With growth in aging population, increasing prevalence of chronic diseases, and global pandemics, there is immense pressure on healthcare systems and AI is more important than ever to support those systems. Perhaps, the most successful area whereby AI has exhibited immense promise is in the diagnosis and prediction of disease outbreaks as illustrated in **Table 1** [2]. Software applications such as BlueDot and HealthMap have been of great help when it comes to identifying new diseases, at times even earlier than the global health organizations. For instance, BlueDot was the first to identify abnormal findings associated with COVID 19 back in late 2019, thus putting incredible emphasis on the efficiency of AI as the leading technology for early risk indication [3]. Similarly, tools such as Nextstrain powered by AI, have enabled us to track the evolution flow of viruses in real time in addition to identifying exactly how these viruses mutate and spread out within society. This information is critical in determining the appropriateness, scope, timing and location of public health interventions.

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Table 1 Disease Outbreaks Predicted with the use of Artificial Intelligence. Timely prediction of disease outbreaks is critical for resource allocation and planning prevention strategies and interventions. AI with its immense data collection and analysis capabilities provides numerous opportunities in predicting disease outbreaks early and providing remedial solutions. Some of the disease outbreaks successfully predicted are listed within this table

Disease Outbreaks Predicted with the use of Artificial Intelligence
Dengue
Tuberculosis
COVID-19
Cholera
Malaria
Influenza
Hepatitis
Zika virus
Brucellosis
Hand, Foot and Mouth Disease
Crimean-Congo Hemorrhagic Fever
West Nile Virus

Additionally, AI also helps the healthcare providers manage resources and downwards costs [4]. Companies such as the Health Care Cost Institute and Health Catalyst implement artificial intelligence to predict intensifying trends in healthcare and the formulation of effective strategies particularly for hospital readmissions and enhanced client experience. This predictive power enables governments and health institutions to disperse their resources better during calamities such as the COVID-19. AI has also proven to have been helpful in modeling of vaccine distribution and increasing the efficiency of the distribution process [5]. During the COVID-19 vaccinations, worldwide AI-enabled platforms such as the Rockefeller Foundation and Gavi Vaccine Alliance played an important role in determining the supply and distribution logistics of vaccines in the lower and lower to middle income countries. These AI systems were indispensable in order to deliver vaccines to targeted populations as soon as possible and minimize both death and infection risks. Another important area of focus to use AI in the public health domain is to embark on health equity. Tools are being developed to help diagnose health inequalities as well as formulate effective solutions to ensure a just health care model. The coronavirus pandemic has finally put into gear programs like Maven Clinic and the Aetna Health Equity Index all of which utilize AI techniques to fight poor maternal health and socioeconomic distribution respectively. These programs help administrators to provide focused and more appropriate care interventions for different communities and close the gaps in rates of health disparities [6].

AI also assists in providing diagnostic support for clinicians resulting in an earlier and an accurate diagnosis with higher confidence. Some of the diseases that reported added utility of diagnosis with use of AI are illustrated in **Figure 1** [7]. IBM Watson, for example, is a powerful AI application that is applied to analyze heath information. PathAI, another AI tool, is employed in preliminary cancer diagnosis. Employing AI in wearable technology facilitates smart monitoring of health 24/7 and provides timely profiling in chronic diseases. Telemedicine and virtual health assistant's user base is growing rapidly, especially since the COVID-19 pandemic. Autonomous systems such as Woebot Health and Ada Health which offer mental health support and chronic disease guidance to patients in locations where access to traditional health services may be limited. Most impact is noted with alleviating pressure on the already strained healthcare sector and yet able to offer continued resources for vulnerable patient populations [8,9].

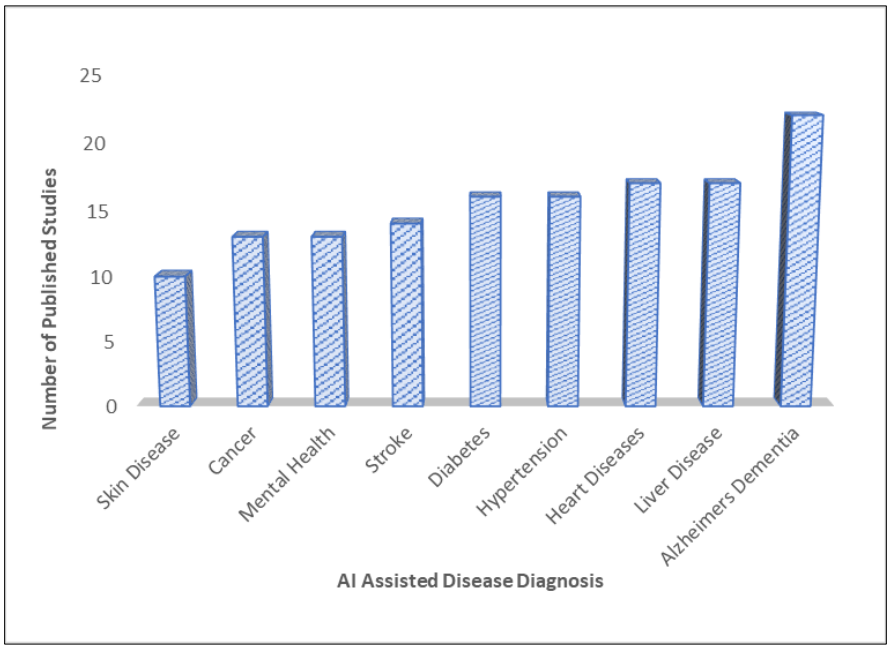

Figure 1 Role of AI in Disease Diagnosis.

This image illustrates the various diseases that can be detected early and accurately with the use of AI algorithms adding value to the conventional diagnostic methods. Early detection can lead to prompt management such as diet, exercise and lifestyle changes etc. and result in overall improved health outcomes as well as reduction in overall health care costs compared to presentation at an advanced stage.

However, AI comes with its own challenges and issues, predominantly of security, bias and safety [10]. The advantages and challenges of AI in public health are illustrated in Figure 2 and would be discussed further with case examples.

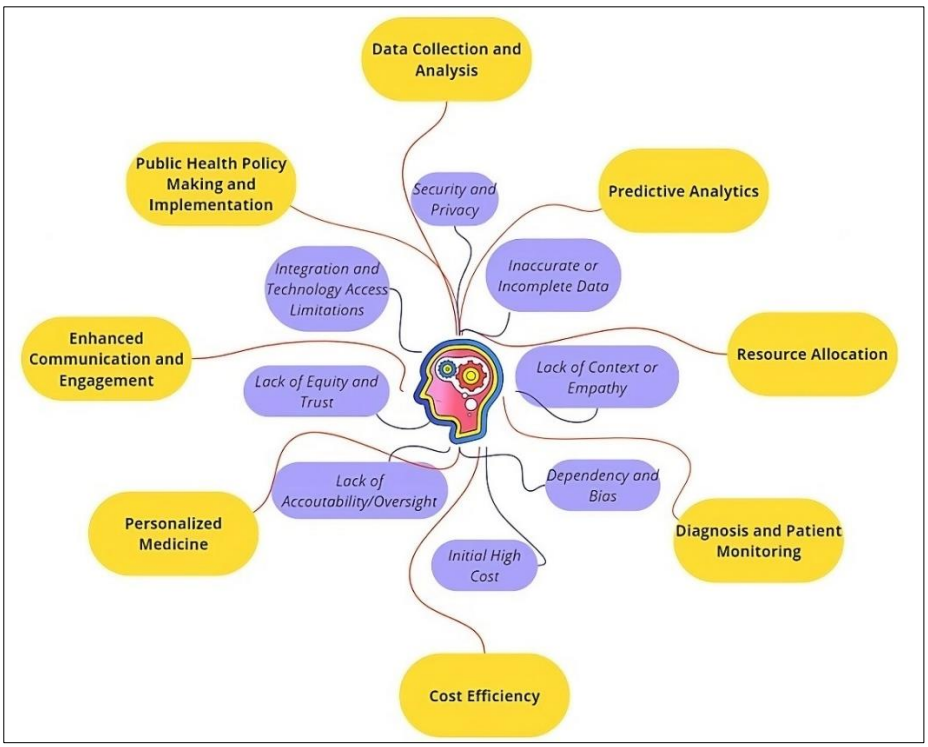

Figure 2 Highlights and Challenges of AI in Public Health.

The graph illustrates the advantages and disadvantages of artificial intelligence technology in the public health sector. It is important to understand the complex interplay and limitations of AI technology to innovate and benefit the most.

2. AI Strategies/Methodologies and Outcomes

2.1. AI Strategies and Methodologies

The advancements that AI brings to the public health field are due to the approach, tools and methods it brings that allow for real-time analysis and anticipation of results. Some of the commonly employed AI methodologies utilized in public health are machine learning, natural language processing, predictive analysis, and image analysis. All these methods are useful in handling numerous health issues given the fact that there is massive freely available health data that can assist healthcare systems in becoming predictive rather than reactive. Most of the AI systems in the public health sector are based on machine learning [1]. It enables the program to review the available data and make conclusions or find a correlation without programming. This method is useful in methods such as disease surveillance where AI models can be calibrated to pick some features or data that indicate the symptoms that show the eruption of a new disease or occurrence of an outbreak. For example, HealthMap applies machine learning to filter information provided by the news, social platforms, or official reports in order to detect potential disease outbreaks.

Another important method is natural language processing (NLP) through which machines are designed to comprehend the human language. NLP is applied in public health in the form of clinical notes, research papers, social media posts , and more [8, 11]. NLP is useful for tracking trends in social media during health emergencies or disease outbreaks, as well as data mining of clinical documents, and analyzing trends in health promotion interventions. For instance, using AI and NLP, there can be faster identification of early indicators of chronic diseases and other illnesses from EHR data. Analytics models use set tools for machine learning & statistics to develop prognosis of the health future state based on past record & current trends. A lot of programs use these predictive models to determine the likely distribution of diseases, and/or forecast requirements for healthcare and other related resources. For example, Carb- X (Combating Antibiotic-Resistant Bacteria) deploys predictive simulations in the evaluation of antibiotic resistance, for drug development policy making as well as public health [11].

Various image recognition and analysis methods result in a quick and more accurate interpretation of medical imaging and aid in a prompt diagnosis. Using big data of medical images and deep learning algorithms, it is possible to notice certain abnormalities like tumor or some signs of certain disease more effectively than previous techniques. Platforms such as PathAI and AIDOC utilize image recognition in analysis of pathology and radiology representations including cancers or ailments resulting in enhanced patient outcomes [12]. Further, AI has been employed to use big data from various sources including electronic health records, wearable devices, databases, and even social media. These probabilistic models are central to diagnosing diseases, preventing their spread and managing resources optimally [13]. For instance, Nextstrain is an open-source project that provides real time pathogen evolution through the analysis of genomic data operating as a tool for public health authorities to predict outbreaks and responses [14].

2.2. Outcomes

The general result of the application of AI solutions has resulted in numerous benefits across several sectors of public health such as disease control, identification of possible outbreak, allocation of resources and decision-making processes [1]. Integrated and informed global health systems demonstrated the benefits of AI in transforming population health. One of the main benefits is diagnosis and treatment of ailments at an early stage. Machine learning algorithms-based AI models like BlueDot can process massive amounts of data and were the first to inform the authorities of the COVID-19 threat. It is due to this early warning system that governments and public health officials were able to somewhat prepare for the pandemic [9].

AI has also accelerated the pace and precision in detecting illness, especially in clinical, radiological and pathological practices. For example, Freenome AI was designed to detect cancer by analyzing blood samples has increased the early detection of colorectal cancer, thereby increasing patient's survival rates [15]. In the same way, IBM Watson Health has assisted clinicians in the interpretation of a vast amount of medical text for therapeutic recommendations thus reducing diagnostic mistakes [16]. Resource optimization is another important benefit that we anticipate from increased utilization of AI in public health. Enterprise machine learning models created by companies such as Health Catalyst helps organizational perform predictive modelling and foresee the volume of service delivery. AI models were used in real-time to predict future hospital admissions during the COVID-19 pandemic to plan ahead for the amount of available hospital beds, ventilators, masks, etc. This kind of anticipatory resource management was vital in lessening the burden on health care services during the worst of the pandemic [11].

3. Challenges for Implementation of AI in Public Health

The below table 2 summarizes the main challenges attributable to the integration of AI into public health and their potential impact on the provision of health care [10,17,18]. It is important to understand these shortcomings and serious concerns such that provisions can be made to safeguard the integrity and sanctity of health care.

Table 2 Challenges for Implementation of AI in Public Health

Challenge	Description	Impact on Public Health	Examples/Considerations
Privacy and Data Security	Health data is highly sensitive, and AI systems need to comply with strict regulations such as General Data Protection Regulation (EU) and Health Insurance Portability and Accountability Act (US). Issues include data breaches, misuse, and consent.	Mismanagement of health data can lead to data breaches, loss of trust in public health institutions, and legal implications. Non-compliance with regulations can result in fines.	The Cambridge Analytica scandal and increasing scrutiny on how health data is shared across borders.
Bias in AI Algorithms	AI models can be biased due to the data they are trained on, leading to skewed outcomes that disproportionately affect specific racial, gender, or socioeconomic groups.	Bias in AI can exacerbate existing health disparities, leading to unequal access to healthcare, poorer outcomes for minorities, and the perpetuation of systemic inequities.	Examples include racial bias in diagnostic tools or AI-driven health programs that fail to account for social determinants of health.
Integration with Existing Systems	Legacy healthcare systems and outdated infrastructure can hinder the seamless integration of AI technologies into existing workflows, slowing adoption and effectiveness.	The slow adoption of AI could limit its potential benefits, causing delays in the application of AI-driven interventions and underutilization of valuable AI-generated insights	Hospitals and health institutions often struggle with the cost and complexity of integrating AI into electronic health records systems.
Lack of Accountability and Oversight	AI systems lack clear lines of accountability, especially in critical life-and-death decision-making scenarios. There's often uncertainty about who is responsible for AI outcomes.	Failure to ensure accountability in AI applications could lead to medical errors, misdiagnoses, and challenges in regulating AI in critical health decisions.	Lack of established standards for AI oversight in healthcare can increase liability risks for healthcare providers.
Technology Access and Cost	In low-resource settings, access to AI technologies is limited due to lack of infrastructure, training, and funding. AI deployment is often expensive.	The digital divide could worsen health inequalities, leaving underfunded regions or developing countries without access to advanced AI-driven healthcare solutions.	AI applications in telemedicine may be unavailable in rural areas due to poor internet infrastructure.
Public Trust	There is often skepticism or resistance towards AI in healthcare, especially in diagnostic and decision-making roles. Patients and healthcare professionals may prefer human oversight.	Lack of trust in AI could hinder its adoption, causing delays in leveraging AI benefits for diagnosis, treatment planning, and public health campaigns.	Resistance to AI-based diagnostic systems in clinics, with patients seeking second opinions from human doctors.

4. Case Studies and Examples: Utility and Impact on Public Health

4.1. Case Studies

4.1.1. BlueDot

- ***Technology:*** BlueDot is an Artificial Intelligence based platform which uses Machine Learning algorithms in the early detection of infectious diseases. It can forecast the likelihood of an outbreak by analyzing large volumes of data collected from different sources such as announcement of disease outbreak somewhere in the world, ticketing information of passengers traveling via airlines and other official records [19].
- ***Application in Public Health***: BlueDot's effectiveness was highlighted during the COVID-19. The platform warned its users of the outbreak in Wuhan, China, much earlier than the official notifications by international health organizations such as the WHO [20, 21].
- ***Impact:*** BlueDot's ability to identify the COVID-19 represents the benefits of enhanced AI supportive tools in international health monitoring. The platform offers vital lead time for health officials to undertake containment measures to contain the spread of the disease based on the symptoms reported by the users. One of its strengths is the application of a real-time disease detection and prediction system, which will be valuable for increasing society's preparedness for future pandemics and outbreaks [21, 22].

4.1.2. HealthMap

- ***Technology:*** HealthMap is a real-time online disease mapper that identifies illness occurrence and trends by sourcing news articles, blog posts, health forums, and blog posts in multiple languages. It also applies AI to chart disease occurrences in the real-time world, thus helping officials diagnose and control new pathogens [23].
- ***Application in Public Health:*** Specifically, HealthMap was used in the surveillance of the 2014 Ebola outbreak. In this context, HealthMap was of significant help to the public health authorities and humanitarian organizations in providing data combined from different sources on the outbreak allowing users to track visual trends of the disease in real time [24].
- ***Impact:*** There was no doubt about HealthMap's success, it successfully responded to the Ebola outbreak through the integration and visualization of different forms of data. It identified areas that required increased attention due to high case rates resulting in better targeting of efforts and resources for efficient treatment and containment. HealthMap remains an essential technology aid in epidemic monitoring to inform international health policies [11, 20].

4.1.3. Nextstrain

- **Technology:** Nextstrain is an open-source software for pathogen genomics that can predict contemporary pathogen evolution in real time. It displays not only how the virus evolves but also how it spreads, enabling the international community and public health workers better equipped to fight the epidemics.
- **Application in Public Health:** Nextstrain served a massive purpose in mapping out the evolving genetic makeup of the causative virus of COVID-19 known as SARS-CoV-2 [25]. Nextstrain was able to reveal how the virus was changing in real-time paving way for vaccine development and combating new variants of the virus.
- **Impact:** Nextstrain has greatly advanced knowledge dissemination on viral evolution and epidemiology of infections. Its genomic tracking capability has been used to guide vaccine development plans and respond to COVID-19 more efficiently worldwide. This tool shows the importance of AI in the predicting and controlling of pathogen activities in future outbreaks.

4.1.4. Carb-X

- ***Technology:*** Carb-X (Combating Antibiotic-Resistant Bacteria) is an international project that utilizes AI for new antibiotic and other treatments against antibiotic-resistant bacteria.
- ***Application in Public Health:*** AI in Carb-X utilizes big data on bacterial genomes and molecular compounds to look for proteins that can become new antibiotics. This approach significantly accelerates drug discovery with design, identification and reduction in bench to market times. Specifically, it has the potential to address one of the biggest public health threats- antibiotic resistance [26].
- ***Impact:*** Carb-X has driven the discovery of novel antibiotics and can prevent the increasing rates of antibiotic-resistant bacteria, which is presumed to cause millions of fatalities. Therefore, Carb-X uses artificial intelligence to accelerate the discovery of new drugs making a difference in maintaining world health systems' preparedness for the fight against superbugs [27].

4.1.5. Zika Virus Prediction Models [28].

- ***Technology:*** AI based models predict infectious disease outbreaks, including Zika virus. These models use statistical data on the average incidence of disease and trends to predict those and to recognize the communities/ populations who might be most endangered.
- ***Application in Public Health:*** In the Brazil Zika virus outbreak, mathematical models were employed to forecast the potential areas of the virus transmission with reference to climate, population density, and mobility. These models are used in formulating effective strategies in the outbreak preparedness for the public health authorities.
- ***Impact:*** In the Zika outbreak, the use of AI in implementing prediction models also boosted preparedness among the public's health. In particular, the development of the mathematical model made it possible to take the necessary measures in a timely manner, for example, to apply vector control measures and conduct preventive campaigns to prevent the transmission of the virus in vulnerable groups. Multiple predictive models remain vital contributing to understanding the behavior of infectious disease pathogens and aid in the formulation of public health population interventions across the globe.

4.2. Predictive Analytics

The use of AI in public health is specifically important in the use of predictive analytics where, with large data sets, smart systems can make forecasts, allocation of resources and make better decisions resulting in good health care outcomes. There are numerous cases when the organizations utilized AI based predictive analytics to improve decision making and health care solutions. The case studies below demonstrate how organizations in the healthcare sector are using AI predictive tools to deal with different public health issues [8,14].

The Health Care Cost Institute (HCCI) is an influential organization that employs forms of artificial intelligence to project future costs of health care as well as resources needed based on past health trends. Using large-scale data collected from healthcare providers, insurers, and public health systems, big data analytics in HCCI are used to produce machine learning models for forecasting possible scenarios of expenditures in the future and to determine possible deficiencies in resource demands. This makes it possible for the policy makers and healthcare organizations to better define their financial priorities, staffing and distribution of resources and as a result increasing efficiency of the healthcare system. The predictive models that HCCI employs can also determine where potential cost efficiencies exist and thereby work to decrease the cost of healthcare for the entire system and increase the availability of care in the underserved population base.

Another major emerging firm in the anticipation analytics segment is Health Catalyst that leverages information to optimize the health-care systems and health care delivery. Through pulling together two, three, or four data types from EHR, claims databases, and clinical registries, Health Catalyst offers a holistic vision of patient health. One of the implementations is the utilization of algorithms to understand different measures in minimizing readmissions to hospitals. For instance, Health Catalyst's AI system recognizes individuals most likely to be readmitted and proposes those who should receive assessed follow-up care and modified medications [4,7]. This proactive approach has seen many patients being readmitted at much lower rates, better health outcomes and decreased costs. What has been shown through Health Catalyst's use of AI is that through preventative approaches, health systems are able to be optimized at a fundamental level.

In the domain of oncology, Tempus is one of the most active companies leveraging artificial intelligence for creating individual patient treatment strategies. Tempus acquires clinical and molecular information and even genomic sequencing to formulate a treatment plan for cancer. Using machine learning technology, Tempus is able to find correlations between the patient data set and how the individual is likely to behave when subjected to the Tempus treatment plan. This approach does not only improve the accuracy of cancer treatments, but also reduces the time taken by patients to receive the best treatment plans. Artificial intelligence in cancer prognosis enables pro-active clinical interventions and provides optimism for increased survivability and quality life of cancer affected patients. Tempus' input into personalized medicine is one way AI is changing health care since it offers information and parameters for a superior personalized treatment plan [29].

CureMetric and Cardiocare are two organizations that employ artificial intelligence to identify cardiovascular diseases at an early stage. Cardiovascular diseases continue to be among the leading causes of death globally hence the need to adopt measures that will lead to early diagnosis of this diseases and therefore cutting down on cost of health care [30]. Unlike traditional health management models, CureMetric incorporates the use of machine learning for consideration of cardiovascular disease risk factors in the combinations of medical imaging and biometrics. Promoting the identification of certain deviations in heart function or morphology when they are not yet fatal, CureMetric's AI

applications help to ensure that people can be treated before the ailment gets worse. In the same way, Cardiocare makes use of artificial intelligence for early risk indication of cardiovascular decopmensation depending on patient data like blood pressure, current heart rate, and even the real-time activity. Risk assessment allows for timely interventions, like changes in medications or changes in patient behavior that can help drastically decrease overall incidences of subsequent complication such as myocardial ischemia and infarction, and cerebral vascular accidents etc.

Predictive analytics in public health has come in handy in responding to disease outbreaks, directing scarce resources where they are most needed, and enhancing the favorable prognosis for patients that are at high risk of developing a particular disease. Whether in health reforms, addressing the forecast healthcare costs, decreasing the readmission rates, oncology treatments or cardiovascular diseases, the predictive models derived from artificial intelligence aid in decision making in healthcare systems [30]. Data from multiple studies establishes the role of AI in furthering public health such that patients receive more early and preventive care which will consequently enhance health globally besides improving the structure of various healthcare systems across the globe.

4.3. Vaccine Distribution

AI is one of the essential technologies that has significantly contributed towards proper utilization of vaccines in the global market and especially during the current COVID-19 outbreak. Many institutions have adopted AI innovation to enhance functionalities of vaccine distribution and achieve distribution equity especially in developing countries [9, 31, 32].

The Rockefeller Foundation has been leading with the application of artificial intelligence to improve international vaccine logistics. During the COVID-19 crisis, the foundation created models based on artificial intelligence to forecast the demand, vaccine supplies, as well as the distribution process. AI facilitated real-time data processing to help health officials distribute the vaccines to residents who required it. The authorities by themselves would not be able to make these assessments quickly and independently otherwise leading to the under-provision of vaccines for vulnerable citizens [33]. AI tools were implemented on two fronts, firstly comprised of the data analysis to pinpoint where exactly the supply chain was most congested, and secondly where there would be a demand for the vaccines in the future and thus reducing wastage and making sure the vaccines went to the correct areas. Therefore, the use of AI to speed up the import of the vaccines made a great impact in providing relief to the world and overcome the pandemic scourge.

The technology, implemented by Gavi, the Vaccine Alliance has also been employed to enhance vaccine delivery in the low-income countries. AI-based platforms worked with Gavi to create distribution models to provide support to regions that have very few health care facilities. Another example of using AI in vaccine distribution is Gavi's approach in Africa and South Asia for polio and measles immunization. Applying artificial intelligence to parameters such as population density, geographical parameters, and capabilities of health systems, Gavi made better decisions in terms of delivery routes for vaccines, cold chain management for vaccines, and delivery of vaccines to farthest reaches of communities [34]. These activities resulted in better planned vaccination and disease control and consequently less outbreaks as well as better immunization in some of the toughest environments on earth.

Project HOPE, an international health care non-profit organization, is employing the use of artificial intelligence in providing vaccines among affected communities in disaster and conflict-prone regions. One of the specific applications that AI tools were able to achieve for Project HOPE is to evaluate the sentiments of the population of the world based on large dataset drawn from various areas to determine areas that lacks vaccines most and the areas that needs intervention [32]. This has been very crucial in the current century, mainly via the COVID-19 pandemic, where artificial intelligence was used to effectively organize how vaccines should be taken to hard-to-reach communities. AI solutions have been employed in the vaccine distribution through Project HOPE and they have helped manage the implementation process in order to achieve the best outcome by deliveries of vaccines to populations that need them most.

4.4. Health Equity

Healthier Together, an artificial intelligence application, can help identify social determinants of health and focus on delivering interventions to hard-to-reach societies. By employing the principles of machine learning, Healthier Together scans social, economic, and health data to determine individuals and communities at high risk of poor health. An example of this is applying AI for planning comprehensive community health programs, strengthening access to healthy foods, upgrading living standards and improving overall health. Since AI allows for the influx of data to be incorporated into its working formula, which means that the targeting of intervention strategies for diverse populations can therefore be done effectively to achieve health equity.

Maternal care is one area where the Maven Clinic has also been able to use AI in helping underprivileged groups regain their proper health. Health information for expectant mothers is processed by AI tools at the Maven Clinic to fill the gap in maternal services. Through teleconsultations and virtual pregnancy programs, the clinic guarantees the availability to pregnant women in unserved regions to receive proper healthcare services. This AI based system has enhanced the health condition of mothers and the newly born establishing evidence of how technology is able to solve healthcare problems in underprivileged populations [6, 35]. The Aetna Health Equity Index leverages artificial intelligence to help guide ending racism and socioeconomic status in the health field. Using claims data, the Aetna Health Equity Index helps authorities to make policies and design health interventions to minimize the gaps. For example, AI is used to identify minorities' health care access issues for Aetna and thereby create intervention strategies to enhance access to health care so there could be equal health care access for everyone [36, 37].

4.5. Diagnostic Support

The two AI enterprises that have come up with AI solutions to assist cancer diagnosis are IBM Watson Health and PathAI, and their development has greatly boosted early detection. Today, Watson Health leverages machine learning algorithms to evaluate both medical literature and patient information, outcomes of clinical trials to help doctors with diagnosing rare cancers as well manage some of the chronic diseases [38]. Currently, PathAI is more specific limited to the diagnosis of pathology images that are used by pathologists in their diagnosis and treatment plans. A good example of AI success in cancer diagnostics is the identification of rare forms of the disease that regular diagnostics might not identify. AI holds the promise of saving lives by increasing diagnostic accuracy and speed at which treatments can be started.

Aidoc is an AI solutions software designed to help radiologists in detecting critical and life threatening illnesses including but not limited to stroke, pulmonary embolism and intracranial hemorrhage. In real time, the AI system of Aidoc scans through medical images and indicates potential critical findings that may warrant attention at that instant enhancing the rate of diagnosis. These applications integrating AI into radiology imaging have far-reaching implications in the delivery of health care since it dials up the response time for important diseases, thus decreases the danger of complications, and enhances the patients' well-being as illustrated in **Figure 3** [39].

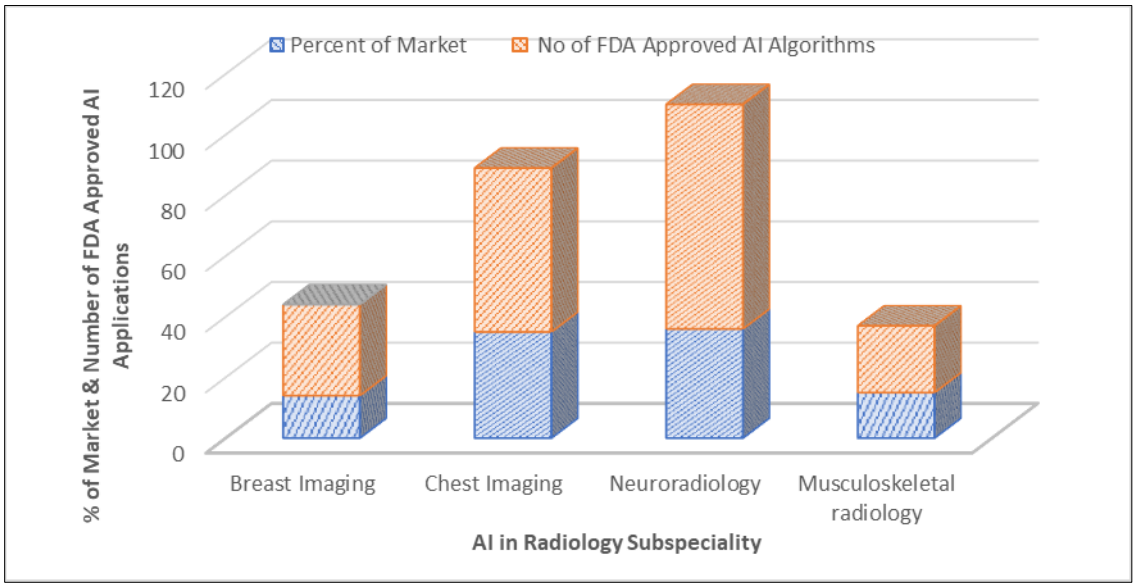

Figure 3 Role of AI in Radiology

This data illustrates some real-world applications in radiology and their distribution/market presence across subspecialities. These applications include detection of breast cancer (digital mammography); lung nodules, pulmonary embolism, pleural effusion, pneumothorax, rib fractures, pneumonia, lines and tubes (chest radiographs and chest computed tomography); stroke, hemorrhage, tumor, aneurysm, dementia, brain injury (computed tomography and magnetic resonance imaging of brain and head and neck); and fractures, osteoarthritis (radiographs). Additionally, AI is also used for non-interpretative purposes such as image quality improvement, dose reduction techniques, conversational dictation software and critical result communication systems etc. to increase productivity.

Mass screening has an immense potential to revolutionize the approach to numerous diseases once the costs scale down. Freenome is an AI platform that analyzes molecular patterns in blood samples to detect early signs of cancer and perform early diagnosis. This strategy has the potential to enhance the specificity of cancer detection and consequently increase early detections and decrease mortality while minimizing invasion thus lowering the costs of health care.

Diagnostic support is the one area where AI has made a significant positive impact, and this has been felt in aspects of accuracy and time. Whether it is early detection of cancer, analysis of life-threatening situations with computed tomography or new blood tests, many healthcare providers are identifying diseases accurately and at an earlier stage because of AI tools.

4.6. Telemedicine and Virtual Health Assistants

Woebot Health is an artificial intelligence improved application that can engage in verbally therapeutic interactions at the moment. The platform provides mental kits to the users through which they can treat their anxiety, depression, and such other issues using cognitive behavioral therapy approaches. Woebot Health was particularly helpful during the COVID-19 pandemic, helping people to cope with isolation, stress and anxiety. The AI self-help chatbots enabled the subjects to carry out conversations which mimicked many sessions of therapy especially when physical therapy sessions were not possible. These AI-driven solutions reduced the mental health burden to populace to a large extent demonstrating ways through which AI can improve availability of psychological support during health disasters.

Several medical chatbots and telehealth apps are able to manage monitoring and treatment of chronic diseases such as mental health, chronic pain, diabetes, hypertension, prostate cancer, breast cancer etc. with the help of AI [40]. For example, Ginger provides mental health care through text-based coaching, while Ada Health utilizes machine learning to interpret patients' symptoms and recommends heathier lifestyles [41]. The use of these platforms keeps patients with chronic diseases such as diabetes, hypertension, or mental health on continuous monitoring/surveillance since they get immediate notification instead of constantly visiting the hospital. Due to the reality of the pandemic and resultant patient lockdown, the features of AI to track a patient's health and offer recommendations have been instrumental in treating chronic diseases. Indeed, owing to this technology, Zyter Telehealth has been able to deliver healthcare services to remote regions. Through its use of artificial intelligence, Zyter's telemedicine platform lets remote healthcare providers conduct a virtual consultation, engage in remote patient monitoring, and assess patient data. Advantages of such monitoring and interactive technology provide help with diagnosis of diseases, monitoring the patient's condition, tracking progress or changes dynamically, and formulating updated treatment plans for patients in remote or underserved areas. A systematic metanalysis of chatbot use reported satisfactory engagement and outcomes in different health care categories as illustrated in **Figure 4** [42].

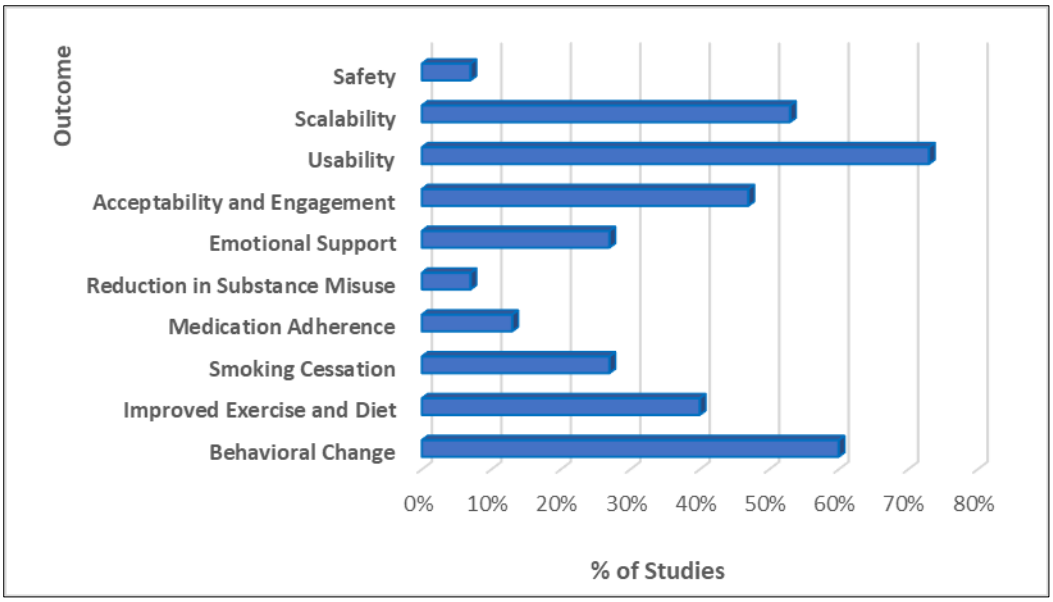

Figure 4 Percentage of Studies Reporting an Outcome with Chatbot Intervention

An illustration of the number of studies with chat bot interventions reporting specific outcomes in a systematic meta-analysis. This emphasizes the diverse functionality and multiple benefits with the use of this AI driven interactive technology to advance health care.

4.7. Public Health Campaigns and Messaging

AI has emerged as a critical methodology to promoting public health campaigns and communicating crises through timely information dissemination and change of people's health behaviors. Examples include the World Health Organization (WHO), Crisis Text Line and Google's Flu Trends, among others. There are other AI-based services like Google's Flu Trends where it tracks the flu through data from the search engine so that the overall public health organizations could be informed of an impending flu season. AI also had a significant function in sharing real-time information during the period of COVID-19. Crisis Text Line, for instance, leveraged on AI to scour through the textual conversation data for huge amounts of SMS to offer mental health services amid the pandemic. These platforms helped the health agencies to post information to the public and made the process of information dissemination relevant, easier and quicker in response to impending public health emergencies.

Computerized and smart-pushed campaigns also eventually help in changing the behavior in public health. Utilizing AI tools to control the public's behaviors, Nudge.ai and the Centers for Disease Control and Prevention (CDC) have applied artificial intelligence with tremendous success and impact. AI propelled messaging campaigns for changing behavior and endorsing healthier behaviors have led to positive results by offering messages and subsequent reminders in accordance with the subject's activities, for example resulting in smoking cessation and adherence to a healthy lifestyle [43]. Self-learning AI systems analyzing the behavior of users and are now able to send specific messages to various user groups and enhance the efficiency of awareness campaigns to improve public health. One of AI's biggest strengths is its ability to make sense of large datasets and deliver tailored messages through the public health system when needed. AI has made it possible to reach people with the right information at the right time to change the negative behaviors resulting in better outcomes and good health practices [42].

Table 3 Below summarizes the various case study examples establishing the significant role of AI in the current public health scenario. These real-world examples immensely contributed to global health from avoiding severe disease outbreaks to early diagnosis, patient monitoring and engagement, and individual as well as community interventions. Exponential growth of AI is opening multiple avenues of huge potential that can significantly transform the health care model and delivery in the near future.

Table 3 Case Examples for Various Positive Impact Categories with the use of Artificial Intelligence in Public Health

Section/Category of Health Impact	Case Study Examples
Disease Surveillance and Outbreak Prediction	BlueDot, HealthMap Carb-X (Combating Antibiotic-Resistant Bacteria), Nextstrain, EpiPredict, Zika Virus Prediction Models, Epidemic Intelligence from Open Sources
Predictive Analytics	The Health Care Cost Institute, Health Catalyst, Aetion, Tempus CureMetric, Cardiocare ,C3.ai
Vaccine Distribution	The Rockefeller Foundation, Gavi the Vaccine Alliance, Project HOPE
Health Equity	Healthier Together, Optum, REACH initiative, Maven Clinic, Aetna Health Equity Index, AarogyaSetu
Diagnostic Support	IBM Watson Health, PathAI, Aidoc, Freenome, Wearable Technology, Atomwise
Telemedicine and Virtual Health Assistants	Woebot Health, Ada Health, Ginger, Zyter Telehealth
Public Health Campaigns and Messaging	World Health Organization, Google's Flu Trends, Crisis Text Line, Sense Health, Truth Initiative, Nudge.ai, Florida Department of Health, CDC and Social Media Analytics

5. Future Directions

Public health stands to benefit from several existing trends that are in the pipeline paving way for the future of AI in the context of public health including early diagnosis, personalized medicine, real-time health informatics and precision

health, all which leverage AI. Such progress has revolutionary implications to change the way community health interventions are carried out, strengthening the prospects of health care medical treatment and its accessibility.

Of all the positive trends, one of the most beneficial yet still developing is the trend toward more individualized health care. Personal level information regarding one's health can be reviewed by the AI models to create highly specific and efficient strategies and personalized or tailored interventions [44, 45]. This approach could further enhance health status in a comprehensive manner by incorporating data from multiple parameters such as the genetic predisposition, lifestyle and environment of an individual [29, 46]. Real-time health monitoring is also powered by AI through wearable solutions and mobile health applications which offer constant and dynamic health statistics. Such tools help people to learn how to cope with chronic diseases and are also helping governmental public health organizations to deal with new trends of diseases [11, 30]. Other recent developments are precision public health which is the application of artificial intelligence to produce responsive public health interventions. AI's ability to sift through big data from multiple source such social determinants of health, genetic, and environmental information make it possible for health officials to pinpoint at-risk groups and provide interventions that are precise. The application of AI for reaching those communities would further ensure health campaigns are effectual for reducing health inequalities and enhance the equity of access to health care [6, 36, 37]. AI abilities are also slowly revealing how it can help in dealing with global health threats. As demonstrated with the recent COVID-19 outbreaks, AI proved helpful in persuading the speedy disbursement of the vaccine, outbreak forecasting, and in resource management in the healthcare industry [13, 32]. In future crises, AI could be utilized to enhance disease detection and pathogen identification and updating health care provision on a real time basis. It could also help extend coverages to clients and individuals, especially in emerging markets, since these innovations present affordable and efficient means of delivering healthcare solutions that include diagnostic tools and telemedicine applications [19].

6. Conclusion

The case studies outlined herein illustrate the use of AI in public health for early disease detection, outbreak prediction, chronic disease monitoring, implementing and achieving immunization, accomplishing health equity, accurate and prompt radiology and pathology diagnostics, conversational chatbot and telehealth support to meet high demand, and public health awareness/engagement and campaigns. These examples established significant role of AI in solving numerous complex issues within healthcare such as prediction of epidemics, identification of diseases and determining the most suitable ways of vaccine distribution. Sophisticated uses of AI in enhancing public health with effective use of decision making is demonstrated with real life examples and success stories such as BlueDot in identification of COVID-19 and IBM Watson Health in cancer detection.

However, several concerns and challenges persist with regard to the achievements of frontier research on AI in the field of public health. Challenges of privacy, fairness and bias in the design and application of AI, availability/affordability of technologies and apathy of the public towards technology must be addressed to ensure AI in delivery of healthcare is fair and ethical. Furthermore, the challenges of integrating AI into current health systems and policies, especially in low to middle income countries, remain a continuous hurdle. However, AI has the ability to revolutionize public health in very significant ways and having a few challenges resolved by AI means effectively changing the face of healthcare for the better. As the AI technologies continue to advance, the essential framework will require harmonization among all stakeholders- government authorities, healthcare institutions, technology industries, public health departments as well as the users. Behavioral norms and guidelines are required for the creation and application of AI, so it contributes positively to all communities with special attention to the less privileged. Thus, it could be concluded that AI has virtually limitless possibilities for presenting a positive impact on the health of populations in the future. Continued improvement and universal adoption of AI in public health requires a visible, accountable and ethical structure, increased access to AI structures for all people, and collaborative efforts globally towards a healthier population.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be dislcsoed.

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