Artificial Intelligence in Post Pandemic Healthcare

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Chapter 9. Artificial Intelligence in Post pandemic Healthcare

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Abstract

One of the most historical and devastating phenomena in the current century was Covid 19 pandemic. A major part of the world population was infected due to the sudden outbreak and claimed many lives. The pandemic impacts almost every aspects of the world infrastructure. The major hit back is observed in the healthcare sector. To combat the virus outbreak, artificial intelligence is emerged to be an innovative strategy. AI mimics the human mind which can thinks like a human mind and have the complex problem-solving ability with much less time compared to human mind. At the time of pandemic, Machine Learning (ML) and Deep Learning (DL) algorithms along with AI innovations is countered to combat the outbreak. Supervised ML techniques such as tree-based models (random forest, gradient boosted trees), support vector machine models, K- nearest neighbor algorithms are extensively used. The amalgamation of Artificial Intelligence (AI) and Internet of Things (IoT) termed as AI-IoT is used for the containment of the disease. AI-IoT helps by forecasting the pandemic progress, real time data analysis, contact tracing, remediation control, estimation of the number of cases and death rate, workload reduction of healthcare workers, drug discovery and development etc. In the postpandemic era, due to digitalization and AI can strengthen and properly maintain the healthcare sector. Using AI, limited healthcare resources can be managed, personalized patient management and treatment plans can be done. Moreover, AI based strategy can be useful for the diagnosis, prevention and management of diseases such as cancer, hypertension, diabetes and other communicable diseases. Telepharmacy sector can be improved by adopting AI based algorithms which can reduce the burden of healthcare workers. The benefits of including AI in the healthcare sector are early detection of the diseases, improved patient monitoring, improved workflow management and cost saving in the healthcare sector.

Keywords: Covid 19, Machine Learning, algorithms, Internet of things (IoT), Patient management, Tele pharmacy, Patient monitoring.

1. Introduction

Corona viruses come from a family of coronaviridae. These are single-stranded RNA viruses with positive sense; their genomes are roughly 26–32 kilobases in size. The corona virus commonly causes infections to the upper respiratory tract. Most of the virus of this family is non-infectious for humans (Jain & Barhate, 2020). Only a small number of the corona virus family's viruses—229E, NL63, OC43, HKU1, SARS-CoV, and MERS-CoV—are known to infect humans (Lone & Ahmad, 2020). Corona viruses are round shape and approximately 80-120 nm in diameter. They have a characteristic club-shaped spike like projections on their outer structure and for this reason they are named as corona virus. There are four main structural proteins in the corona virus; these are spike proteins (S), envelop protein (E), membrane bound protein (M) and nucleocapsid proteins (N) (Khadse NA et al., 2020).

Numerous instances of pneumonia with no identifiable cause were reported from Wuhan province in China in December 2019. By January 2020, the causative organism was identified and named as Severe Acute Respiratory Syndrome Corona virus 2 (SARS-CoV 2) (Cevik et al., 2020). Over the course of one month the virus spreaded across the globe and on January 30, 2020, WHO declared SARS-CoV 2 as pandemic (Cevik et al., 2020). Many methods were encountered to detect the infections in the communities during the pandemic; mostly used methods were RT-PCR test, rapid antigen test and serology based antibody test (Mercer & Salit, 2021).

According to WHO database, nearly 0.77 billion of cases and 7 million deaths are reported till mid-January 2024 (*Coronavirus Disease (COVID-19)*, 2023). During the pandemic, it greatly affects the healthcare segment globally. The COVID-19 pandemic highlights the most vulnerable components of the global healthcare infrastructure. Lack of healthcare facilities, shortage of infrastructure in existing facilities, insufficient healthcare providers etc were somehow responsible for such a deadly outbreak (Filip et al., 2022).

Artificial intelligence (AI) is often called as intelligent agent. It aims to mimic human cognitive functions in machines (Das et al., 2015). AI refers to simulate human minds in learning and analysis, and can work to solve problems. In clinical perspective, AI can have the potential to revolutionize the healthcare settings globally and can be a worthy tool to assist the healthcare practitioners (F. Jiang et al., 2017).

2. Challenges faced by healthcare system during pandemic

Healthcare system is a unique and complex by its own. The healthcare establishments vary between different countries. The Covid-19 pandemic had a lasting effect on the world's healthcare system. As the pandemic progresses, new challenges continue to evolve. Globally the pandemic pointed out few major flaws in the global healthcare infrastructure. In the early days of the outbreak, the healthcare system faced some challenges, these are:

2.1 In house challenges:

The in-house challenges involves, the challenges faced by hospitals and other healthcare facilities. The healthcare system has two major pillars: Public healthcare services (Government hospitals) and Private healthcare services. The healthcare services had the major burden at the time of the outbreak. Some of the Key challenges are:

A. Lack of materials support for the frontline workers

The sudden outbreak of Covid 19 has hampered global supply of essential commodities like PPE kits, surgical gloves, and sanitizers. Factors contributing to delays include shortages of raw materials, machines, labor, overdependence on China, border closures, and export bans (Asian Development Bank et al., 2020; Torrentira, M, 2020).

According to Ahmed *et al.*, In the United States of America, 15% of doctors reported not having access to N95 respirators; moreover, 20% did not have gloves; roughly 12% lacked face shields, and roughly 50% lacked access to full robes or coveralls. Furthermore, roughly 7 percent of physicians said they had to treat COVID-19 patients without the proper personal protective equipment (PPE), and over 80 percent said they had to reuse some PPE. Also in Pakistan, N95 respirators were only available to 37.4% of Pakistani healthcare personnel, gloves to 34.5%, face shields or goggles to 13.8%, and full suits or gowns to 12.9% (Ahmed et al., 2020).

B. Shortage of healthcare workers

Healthcare workers are the backbone of the any countries healthcare infrastructure. During the pandemic, shortage of healthcare workers was observed globally. Due to sudden spike of cases during first & second wave, even healthcare professionals having little or no experience came forward to fulfill the shortage (Filip et al., 2022).

Limited human resource in the healthcare facilities puts extra burden and workload on the existing workers during the outbreak. Moreover, due to infections significant numbers of healthcare professionals were died and the causes more burden to existing workers (Razu et al., 2021).

C. Disruption of non-covid healthcare service

The global outbreak of COVID-19 has had a dramatic effect on healthcare systems across the globe, leading to a notable disturbance in non-COVID healthcare services. Consequently, the delivery of routine medical services, including screenings, elective surgeries, and ongoing treatments for chronic conditions, has been severely affected. The prioritization of COVID-19 response measures, such as lockdowns, resource reallocation, and infection control protocols, has led to delays, cancellations, and reductions in access to essential non-COVID healthcare services. This disruption has raised concerns about the short and long-term consequences for patients, healthcare providers, and health outcomes beyond the scope of the pandemic itself (Mahendradhata et al., 2021; Sengupta et al., 2021).

Lockdowns have reduced psychiatric emergency admissions, with anxiety disorders being the most common diagnosis in Spain and Switzerland, and intellectual disability, neurotic, stress-related, somatoform, and affective disorders in Germany (Tuczyńska et al., 2021). According to the questionnaire-based study carried out in Nigeria, patients' chronic diseases grew worse during the COVID-19 pandemic because they had less access to necessary medications than they did before the pandemic. People have started looking for alternative treatment options as a result of the reported increase in the cost of medications for both acute and chronic illnesses (Tuczyńska et al., 2021). Furthermore, projections of the COVID-19 pandemic's indirect effects on maternal and newborn health in Nigeria, Pakistan, India, and Indonesia over a one-year period have resulted in a further 31,980 maternal fatalities, 395,440 infant deaths, and 338,760 stillbirths (Mahendradhata et al., 2021).

D. Supply chain disruption

The COVID-19 pandemic has disrupted global supply chains, particularly in developing nations. Raj et al. identified ten major challenges, including demand uncertainty, supply volatility, material scarcity, delivery delays, and labor scarcity. They used the Grey-Decision-making Trial and Evaluation Laboratory approach to analyze these issues, emphasizing the impact of supply inconsistency. The article offers practical advice for navigating the post-pandemic supply chain (Raj et al., 2022).

E. Challenges in disease testing, screening and tracing

Effective disease testing, screening, and tracing during the COVID-19 pandemic have encountered multifaceted challenges. While timely and accurate diagnosis is pivotal for clinical management, conventional methods like biochemical assays, ELISA, and RT-PCR have been hindered by their time-consuming nature and high costs. Moreover, these methods often fail to identify past infections crucial for community-wide surveillance and mitigation efforts. Particularly challenging is the identification of asymptomatic carriers. In this context, rapid antibody-based tests have emerged as frontline tools for mass testing, offering a more practical approach to initial diagnosis amidst the evolving landscape of a viral pandemic (Augustine et al., 2020).

2.2 Social/Community challenges

The onset of the pandemic unleashed a wave of unprecedented challenges within our social and community landscapes. As communities grapple with the complexities of public health measures, economic instability, and social isolation, issues such as inequity, access to healthcare, and systemic disparities have been magnified. The pandemic has not only tested the resilience of our social fabric but also underscored the urgent need for collaborative solutions that address the multifaceted challenges faced by individuals, families, and communities worldwide. Some of the key social challenges are listed below:

A. Misinformation and Infodemic

The COVID-19 pandemic has exacerbated misinformation, with social media posts originating from unreliable sources and bots. Despite efforts by social media companies and public awareness, the problem persists. Governments must implement legislative regulations, investigative responses, and campaigns, while consumers must exercise critical thinking and responsible content sharing to mitigate the infodemic's impact (Greenspan & Loftus, 2021).

Misinformation during the Covid-19 pandemic has significantly impacted public perception, behavior, and memory, leading to an "infodemic." Cognitive science research shows that misinformation distorts memory and influences beliefs. To combat this, social media companies must implement measures, while users must discern information reliability. Strategies integrating cognitive science research can enhance media literacy and promote accurate information dissemination (Datta R & Litt TB, 2020).

B. Health inequities & Vulnerable populations

The COVID-19 pandemic has exacerbated health disparities, particularly among vulnerable populations. Research shows that individuals with lower income, education, or ethnic minorities face higher risks. Communication inequalities, particularly in education, contribute to these disparities. Targeted strategies and further research are needed to address these inequalities and ensure equitable access to resources (Häfliger et al., 2023).

Moreover, vulnerable populations of psychiatric patients have been disproportionately affected by the COVID-19 pandemic, compounding existing global health disparities. Pregnant women, children with impairments, ethnic minorities, and residents in rural and urban areas encounter particular difficulties that aggravate mental health consequences. To address these disparities, social programs aimed at reducing discrimination, enhancing community resilience, and overcoming systemic barriers to care are essential (Diaz et al., 2021).

C. Patient and population mental health impact

The COVID-19 pandemic has significantly impacted mental health, leading to conditions like depression, anxiety, and traumatic stress. To address this, researchers need to identify risk factors, anticipate outcomes, and develop intervention strategies. Innovative approaches, including non-traditional models and tailored preventive interventions, have the potential to effectively address mental health needs during and beyond the pandemic (Boden et al., 2021).

D. Long term health effects & post covid syndrome

During the COVID-19 pandemic, post-COVID syndrome emerged, affecting 10%-35% of individuals and 85% of hospitalized patients. Common symptoms include fatigue, breathing difficulties, mental health issues, chest pain, and changes in taste and smell. Many patients have pre-existing health conditions, increasing the burden on primary healthcare (Del Rio et al., 2020).

3. Innovations in AI during the pandemic

The applications and innovations of AI were observed at the time of pandemic. Some of innovations involved Machine Learning (ML), Deep Learning (DL), Artificial Neural Network (ANN), Internet of Things (IoT) etc.

The field of machine learning is concerned with two interconnected questions: How can computer systems are designed so that they automatically get better with time? And what basic laws of statistical computation, information theory control all learning systems, including those in computers, people, and organisations? Machine learning is the preferred approach in AI for tasks like speech recognition, computer vision, natural language processing, and robot control, as it simplifies training systems by providing desired input-output behavior (Alpaydin, 2021; González García et al., 2019). One of the most significant applications of AI was seen during the pandemic, where the AI helped in various puposes like outbreak detection, contact tracing, disease forecasting etc.

Machine learning (ML) termed as a specific branch of Artificial Intelligence. It is a field within computer science that focuses on empowering computers to improve their performance at tasks without being explicitly programmed for each task. Instead, computers "learn" by gaining experience, typically through analyzing and fitting to data. This process blurs the distinction between machine learning and statistical approaches, as both rely on leveraging data to enable computers to make decisions or predictions autonomously (Bi et al., 2019; González García et al., 2019).

Deep Learning (DL) is also a part of AI and more specifically an upgradation of Machine learning which uses multiple arrays of neural networks to solve complex problems. Deep Learning (DL) enhances classical Machine Learning (ML) methodologies by intricately augmenting model complexity and reshaping data through a multitude of functions, fostering hierarchical data representation across multiple abstraction levels. This approach, leverages automatic feature extraction from raw data, where higher-level features are amalgamations of lower-level counterparts (González García et al., 2019; Schmidhuber, 2015).

Artificial Neural Networks (ANNs) are intricate systems comprising artificial neurons termed units, organized in layers forming a comprehensive network. The network's structure adapts, ranging from a few units to millions, contingent upon the complexity needed to unveil concealed patterns within datasets. Typically, ANNs consist of input, hidden, and output layers. The input layer receives external data for analysis, which then traverses through one or more hidden layers for transformation into meaningful information for the output layer. ANNs offer a notable advantage in modeling complex natural systems with significant inputs, enhancing usability and accuracy. By mimicking the intricate interconnections of neurons in the brain, ANNs demonstrate proficiency in tasks resembling human cognitive functions, illustrating their potential as versatile computational tools (A.D.Dongare et al., 2012; González García et al., 2019; Krenker et al., 2011).

The Internet of Things (IoT) encapsulates the interconnected network of physical objects, known as "things," integrated with sensors, software, and various technologies to enable communication and data exchange with other devices and systems via the internet. By embedding objects with smart capabilities, IoT enhances efficiency, automation, and decision-making processes across various sectors, heralding a new era of interconnectedness and technological advancement (Ghosh et al., 2018).

Amidst the challenges posed by the pandemic, there has been a notable surge in innovations within the realm of Artificial Intelligence (AI). With the persistent threat of new variants and the ongoing need for proactive measures, healthcare providers and organizations have turned to AI technologies to enhance their response strategies. These innovations span a broad spectrum, encompassing advancements in areas such as IoT, cloud computing, deep learning, and blockchain. Particularly, the convergence of AI and IoT technologies has revolutionized healthcare, offering solutions like fog computing, deep learning algorithms, and blockchain integration to bolster efficiency, privacy, and security in patient care and management. These developments underscore the transformative potential of AI in addressing the multifaceted challenges presented by the pandemic, paving the way for more resilient and adaptive healthcare systems in the future (J. I. Khan et al., 2022).

4. Role of AI during pandemic

Amidst the COVID-19 pandemic, artificial intelligence (AI) stands as a crucial ally in various fronts. AI aids in outbreak detection and contact tracing through advanced data analysis, predicts disease trends, and identifies vulnerable populations. In medical imaging, AI assists in detecting COVID-19-related abnormalities, improving diagnostics. AI streamlines treatment monitoring, optimizes resource allocation, accelerates drug discovery and vaccine development, and helps curb misinformation. It plays a crucial role in mitigating pandemic impacts, offering innovative solutions across healthcare and public health.

4.1 Outbreak detection & contact tracing

Artificial intelligence (AI) plays a pivotal role in outbreak detection and contact tracing during the pandemic, leveraging advanced technologies to enhance surveillance and prevention efforts. Natural Language Processing (NLP) is an AI subfield that interprets and extracts meaning from human languages, enabling automated analysis of unstructured data like social media posts and health records to identify potential outbreaks and trends (N. Arora et al., 2020; Shamman et al., 2023). For example, popular social media app Twitter was used along with supervised and semisupervised AI algorithms to detect the regions of the outbreaks such as Wuhan, China (early 2020) (Shamman et al., 2023).

Digital contact tracing, facilitated by AI technologies, serves as a crucial tool in containing the spread of infectious diseases like COVID-19. This approach utilizes mobile applications equipped with Bluetooth and GPS technologies to track individuals' movements and interactions, thereby identifying potential exposures and facilitating timely interventions. AI algorithms in tracing apps enable health authorities to quickly identify individuals near confirmed cases, enabling self-isolation or testing, offering a scalable, efficient solution to curb virus transmission (Agbehadji et al., 2020).

Moreover, AI-powered outbreak detection systems enhance the speed and accuracy of disease surveillance, enabling early identification of potential outbreaks and facilitating proactive intervention measures. AI algorithms can detect health threats by analyzing data from healthcare records, demographics, and environmental factors. This proactive approach helps contain outbreaks, allocate resources effectively, and mitigate the impact of infectious diseases on public health (Agbehadji et al., 2020; N. Arora et al., 2020; Shamman et al., 2023).

4.2 Disease Forecasting

AI based approaches can forecast the quantity of fatalities and positive cases in any given area. AI can assist in identifying the most susceptible nations, areas, and individuals so that appropriate action can be taken (Vaishya et al., 2020).

For example, machine learning (ML) regression and statistical models helped to predict cumulative patient counts in Brazil at the early stages of the pandemic (Shamman et al., 2023).

Advanced AI models and techniques like NRANN, ANFIS, HFFA, BNN, LSTM, VAE, and SSA can improve surveillance and response strategies in healthcare. These models analyze complex datasets, identify patterns, and provide a mathematical framework for interpreting data, enabling timely interventions (Elsheikh et al., 2021).

4.3 Detection of covid-19 by medical imaging

Artificial intelligence (AI) plays a critical role in the detection of COVID-19 on medical imaging during the pandemic, particularly in cases where clinical features of SAR-CoV-2 infection overlap with those of other viral illnesses. Chest X-rays (CXRs) and CT scans, while often revealing non-specific bilateral infiltrates and ground-glass opacities, respectively, pose challenges in accurate diagnosis. However, efforts to leverage deep learning (DL), specifically Convolutional Neural Networks (CNNs), for COVID-19 detection from chest imaging have shown promise. CNNs, designed to process input images through hierarchical structures, offer a robust framework for classification tasks. By pretraining CNNs on broader datasets and fine-tuning them with limited medical data, researchers enhance AI models' performance, demonstrating their potential to outperform fully trained networks in specific scenarios (Khemasuwan & Colt, 2021).

4.4 Treatment monitoring of the infected patients

AI has significantly aided in monitoring COVID-19 treatment, including quarantine and self-isolation protocols, using smartphone apps, algorithms, cameras, and GPS. Despite concerns about civil liberties, supply restrictions, and detection challenges, AI-driven monitoring systems have proven instrumental in managing and mitigating the pandemic's impact on public health (Shamman et al., 2023).

In clinical management, AI technologies have revolutionized diagnostics, treatment monitoring, and health tracking for COVID-19 patients. Machine learning (ML) algorithms and virtual treatment platforms facilitate remote consultations, telemedicine, and AI-based diagnostics, enabling healthcare providers to diagnose patients, track their health status, and make informed clinical decisions. By enhancing diagnostic accuracy, risk prediction, and service delivery efficiency, AI empowers healthcare professionals to effectively manage patient care amid the pandemic. However, concerns persist regarding medical privacy, the need for proper evaluation of patients, and the potential breakdown of AI-powered machinery (Shamman et al., 2023).

4.5 Workload reduction of Healthcare workers

AI is assisting healthcare workers during the COVID-19 pandemic by facilitating early diagnosis, treatment, and training initiatives. It aids in managing cases, providing comprehensive training modules, automating processes like training dissemination and treatment determination. AI-powered telemedicine solutions reduce hospital visits and infection transmission, while medical chatbots provide remote consultations, enhancing accessibility and efficiency in critical care services (N. Arora et al., 2020; Vaishya et al., 2020).

4.6 Drug and Vaccine development

Artificial intelligence (AI) has revolutionized drug discovery efforts during the COVID-19 pandemic, offering sophisticated algorithms and techniques to expedite the identification of potential therapeutics. Innovative algorithms such as the arbitrary-order proximity embedded deep forest (AOPEDF) and deep learning-based drug–target interaction models have enabled the prediction of drug-target interactions and the repurposing of existing compounds for COVID-19 treatment. Additionally, as demonstrated by Zhang et al., proposed a densely fully connected neural network (DFCNN) pipeline where AI algorithms enable the quick screening of millions of chemicals against targets. These AI-driven strategies not only hold promise for COVID-19 drug discovery but also pave the way for developing novel treatments against other infectious diseases, underscoring the transformative potential of AI in advancing global healthcare initiatives (G. Arora et al., 2021). Hu et al. found eight SARS-CoV-2 proteins as potential drug targets using a deep learning model. They identified abacavir and darunavir as compounds with high binding affinity, with darunavir being the focus of a clinical trial in China. This highlights the potential of AI in drug discovery (Hu et al., 2022).

AI facilitates the development of therapies and vaccinations far more quickly than is typically possible. It also helps with clinical trials that are conducted while a vaccine is being developed (N. Arora et al., 2020; Vaishya et al., 2020). Ong *et al.*, used AI to analyze SARS-CoV-2 protein sequences and human coronavirus strains. They used Vaxign-ML, a machine learning algorithm, to predict protegenicity scores. They identified six proteins, including the spike protein, as potential vaccine targets. The study highlights the importance of AI in vaccine development (Ong et al., 2020).

4.7 Protein Structure Prediction

Artificial intelligence (AI) has emerged as a transformative force in drug discovery efforts during the COVID-19 pandemic, particularly in predicting the structures of key proteins essential for virus entry and replication. By harnessing advanced algorithms such as AlphaFold and DeepTracer, researchers can accurately predict the structural configurations of crucial viral proteins, including membrane proteins and RNA polymerases. These predictions not only offer valuable insights into the molecular mechanisms underlying viral infection but also provide a foundation for the development of targeted therapeutics. For instance, the AlphaFold algorithm utilizes deep residual networks (DRN) to predict the structures of membrane proteins and various domains of SARS-CoV-2, paving the way for expedited drug discovery programs. Overall, AI-driven approaches hold immense promise in accelerating the discovery and development of novel antiviral agents to combat the COVID-19 pandemic (N. Arora et al., 2020; Swayamsiddha et al., 2021).

4.8 Curbing spread of misinformation

The COVID-19 pandemic has spawned an infodemic due to the overwhelming volume of information available. Analyzing data from social media platforms like Twitter and Facebook enables the understanding of public knowledge, awareness, and practices toward the virus, aiding in the dissemination of accurate information. Machine learning techniques offer insights into trends and sentiment analysis, assisting in debunking false information and mitigating rumors. Additionally, AI techniques play a crucial role in providing updates on recovery rates, healthcare accessibility, and emerging evidence in diagnosis and treatment, offering clarity to clinicians and alleviating public fear and panic (N. Arora et al., 2020).

5. Role of AI in postpandemic healthcare infrastructure

5.1 Clinical decision making for patients in healthcare organization

AI is playing a crucial role in healthcare decision-making, particularly in risk stratification for surgical procedures. Machine learning models assess patient risk levels, identifying high-risk individuals and optimizing resource allocation. This integration of AI-driven risk stratification models can enhance preoperative support for high-risk patients, ultimately improving patient outcomes (Giordano et al., 2021).

AI is revolutionizing patient outcome optimization by providing data-driven insights for clinical decision-making. ML methods optimize patient care, from medication dosing to surgical interventions, analyzing complex patient data from EHRs. Reinforcement learning models are particularly promising for identifying optimal treatment policies (Giordano et al., 2021).

Furthermore, AI can be used in early warning systems for acute patient decompensation, detecting physiological trends in EHRs. These systems offer a proactive approach to patient monitoring, enabling timely interventions to mitigate adverse outcomes. Despite challenges, ongoing research is advancing AI capabilities (Giordano et al., 2021).

5.2 Health information Management in Healthcare Organizations

In the post-pandemic healthcare landscape, the integration of artificial intelligence (AI) into health information management (HIM) within healthcare organizations is set to revolutionize practices. AI applications, particularly in automated medical coding, diagnosis specificity, and early detection information, hold promise for enhancing patient care and operational efficiency. While computer-assisted coding (CAC) systems utilizing natural language processing (NLP) show potential to streamline coding tasks, successful implementation requires workflow adjustments and HIM oversight. Additionally, AI's role in early detection of conditions necessitates revisions to coding guidelines to capture suspected or impending diagnoses, highlighting the need for interdisciplinary collaboration to navigate complexities and ensure effective integration of AI into HIM practices post-pandemic (Stanfill & Marc, 2019).

5.3 Precision medicine

The role of artificial intelligence (AI) in precision medicine after the pandemic is pivotal across various domains, including genomic considerations, environmental factors, and clinical parameters. Through machine learning algorithms, AI aids in genotype-driven medication prescribing, ensuring personalized treatment plans based on genomic variations. In diseases like medulloblastoma, AI facilitates the identification of molecular subgroups, refining treatment strategies to administer the most effective therapies while minimizing adverse effects. Furthermore, AI's integration with radiogenomics enhances cancer imaging analysis, predicting treatment response and toxicity risks. Environmental factors, such as patient demographics and resource availability, are also incorporated into therapy planning with AI's assistance, ensuring equitable care delivery. Additionally, AI algorithms analyze clinical data to stratify patients for therapy based on co-morbidities and predict treatment outcomes, contributing to more tailored and effective interventions (Alowais et al., 2023; Johnson et al., 2021).

5.4 Prediction of population health

Predictive analytics is being used more and more in population health management to pinpoint and direct health interventions. Predictive analytics is a branch of data analytics that makes extensive use of AI, ML, data mining, and modelling. It examines both recent and past data to forecast the future (Schwalbe & Wahl, 2020).

During the postpandemic era, the application of AI can be extensively used for mortality and morbidity risk assessment for the sake of public healthcare. For example, in order to evaluate the probability of dengue fever severity, Phakhounthong et al. applied machine learning algorithms on administrative records from a large tertiary care hospital in Thailand (Phakhounthong et al., 2018).

AI will significantly aid in disease outbreak prediction by analyzing vast datasets, detecting early warning signs, and enhancing surveillance systems. This will enable proactive measures to contain potential outbreaks, bolster preparedness, and foster a more resilient global response to future health crises (D. Jiang et al., 2018).

5.5 Contactless healthcare service

The COVID-19 pandemic has accelerated the adoption of contactless services, facilitated by advanced technologies like AI, IoT, VR, and AR. These services, which offer non-face-to-face interactions, have gained prominence in sectors like distribution. The pandemic has accelerated digital transformation, positioning ICT at the forefront of the post-pandemic era (Alowais et al., 2023; Lee & Lee, 2021).

The global telemedicine market has seen a significant growth due to the COVID-19 pandemic, with projections of $175.5 billion by 2026. This growth is attributed to chronic disease prevalence, smartphone adoption, and cost-effective healthcare solutions. However, telemedicine's full potential requires advanced ICT integration and regulatory relaxation. As COVID-19 becomes an endemic virus, AI and big data analytics will become crucial in healthcare. Post-pandemic, telemedicine services must adapt to changing healthcare landscapes (Alowais et al., 2023; Fikry et al., 2023; Lee & Lee, 2021).

5.6 Mental health support

AI chatbots are transforming mental health services by providing empathetic interactions and resources. With digital government policies, these platforms, like Woebot, EMMA, SERMO, and Tess, offer accessible and cost-effective solutions for anxiety and depression. The COVID-19 pandemic has increased demand for digital mental health interventions, prompting increased investment in chatbot technologies. These chatbots address loneliness and uncertainty, promoting mental resilience and personalized support worldwide (Damij & Bhattacharya, 2022).

5.7 Infectious Disease Testing

AI and machine learning are transforming infectious disease testing post-pandemic, improving diagnostic accuracy and speed. AI/ML applications have shown potential in early detection of Lyme disease and meningitis, enhancing testing accuracy and streamlining processes. By analyzing diverse datasets and identifying key diagnostic features, AI/ML technologies can prevent disease progression and improve patient outcomes (Alowais et al., 2023; Tran et al., 2023).

Furthermore, AI/ML-driven approaches can improve infectious disease diagnostics, particularly in early recognition of life-threatening conditions like sepsis. By leveraging EMR data and integrating clinical parameters, AI/ML models can enhance diagnostic accuracy and specificity, particularly for special sepsis populations. This technology holds promise for improved patient care and public health outcomes (Kaur et al., 2021; Tran et al., 2023).

6. Benefits & limitations of AI in postpandemic healthcare

A. Benefits of AI

- *Enhanced Diagnostic Accuracy:* Large amounts of medical data, such as imaging scans, lab findings, and patient records, can be analysed by AI algorithms to help medical personnel diagnose patients more accurately, particularly in cases of complex or uncommon illnesses.

Khalifa et al. highlight AI's potential in diagnostic imaging, suggesting funding, moral standards, and patient-focused research. They recommend teamwork for effective integration and healthcare inequities (Khalifa & Albadawy, 2024).

- *Streamlined Workflow:* AI-powered solutions can reduce administrative costs and free up time for healthcare providers to concentrate more on patient care by automating repetitive administrative chores like monitoring electronic health records, making appointment schedules, and processing paperwork (Johnson et al., 2021).
- *Personalized Treatment Plans:* AI can assist in customising treatment plans and interventions to each patient's distinct traits, including genetics, lifestyle factors, and medical history, by analysing individual patient data. This will result in more efficient and individualised care (Alowais et al., 2023; Johnson et al., 2021).
- *Predictive Analytics:* AI-driven predictive modeling can forecast healthcare demands, identify at-risk populations, and predict disease outbreaks, enabling proactive interventions and resource allocation to mitigate the spread of infectious diseases and improve population health (Alowais et al., 2023; D. Jiang et al., 2018; Phakhounthong et al., 2018).
- *Remote Monitoring and Telemedicine:* AI-powered telemedicine systems and remote monitoring equipment can improve access to healthcare services, especially in underserved or distant locations, and allow continuous monitoring of patients' health state. They can also make virtual consultations easier (Fikry et al., 2023; Lee & Lee, 2021).
- *Drug Discovery and Development:* By evaluating enormous volumes of biological and chemical data to find promising drug candidates, anticipate medication interactions, and improve

treatment regimens, artificial intelligence (AI) algorithms might hasten the drug discovery process and hasten the development of new treatments (Hu et al., 2022; Ong et al., 2020).

- *Continuous Learning and Improvement:* Healthcare practitioners may stay updated on medical knowledge and best practices by using AI systems, which can learn continuously from fresh data and feedback. This improves patient care and results over time.

Limitations of AI:

- *Data Bias and Quality:* AI algorithms rely heavily on the quality and representativeness of the data they are trained on. Biases in healthcare data, such as underrepresentation of certain demographics or populations, can lead to biased AI predictions and recommendations, potentially exacerbating healthcare disparities and inequities (Daneshjou et al., 2021).
- *Lack of Transparency:* A lot of AI algorithms function as "black boxes," which means that it is challenging to understand or comprehend how they make decisions. Healthcare practitioners may find it difficult to comprehend and trust AI-driven advice as a result of this lack of transparency, especially in situations where crucial decisions must be made (Daneshjou et al., 2021; Kiseleva et al., 2022).
- *Patient Privacy and Data Security:* For AI systems to work well, they frequently need access to a lot of private patient data. It is crucial to protect the privacy and security of this data since data breaches or improper use could have detrimental effects on patient confidentiality and public confidence in the healthcare system, among other things (B. Khan et al., 2023).
- *Regulatory and Legal Challenges:* The rapid advancement of AI in healthcare poses challenges for regulatory bodies and legal frameworks to keep pace. Unclear regulations and liability issues surrounding AI-driven healthcare technologies may hinder their widespread adoption and integration into clinical practice (Ganapathy, 2021).
- *Interpretability and Accountability:* As AI algorithms become increasingly complex, understanding how they arrive at their conclusions can be challenging. Lack of interpretability makes it difficult for healthcare professionals to verify the accuracy and reliability of AI-generated insights, raising concerns about accountability in the event of errors or adverse outcomes.

Conclusion

In the wake of the pandemic, it has become increasingly evident that the integration of artificial intelligence (AI) in healthcare systems is not just advantageous but imperative for building resilient and effective healthcare infrastructures. AI has demonstrated its potential to streamline processes, enhance diagnostic accuracy, optimize resource allocation, and facilitate remote patient monitoring, all of which are crucial in navigating the challenges presented by public health crises like pandemics. However, to fully leverage the benefits of AI in postpandemic healthcare, it is essential to address pertinent issues such as data privacy, algorithm transparency, and ethical considerations. Healthcare institutions can better prepare for future health emergencies while guaranteeing equal access to high-quality care for everyone by integrating AI safely and ethically.

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