Review article

Harnessing the power of Artificial Intelligence for better health data management

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ABSTRACT

The growing role of digital technologies in healthcare presents significant opportunities for countries like Nigeria to improve health outcomes and strengthen health systems. Artificial Intelligence (AI) has emerged as one of the most promising technologies in health data management, revolutionizing how health data is collected, stored, analyzed and utilized. As Nigeria seeks to revolutionize its health information systems for sustainable development, AI offers a pathway to greater efficiency, accuracy, and accessibility in healthcare services. This paper explores how AI can be harnessed to improve health data management in Nigeria, presenting an overview of AI applications in health data, current challenges, and strategies for implementation.

INTRODUCTION

By the late 1990s, advancements in Bayesian networks, artificial neural networks and hybrid intelligent systems significantly propelled bio-informatics research, leading to increased adoption of medical artificial intelligence (MAI)[1]. Artificial Intelligence (AI) can be broadly defined as the science and engineering dedicated to creating intelligent machines capable of performing tasks that mimic human cognitive functions, such as learning and problem-solving. Through algorithms or specific sets of rules, AI systems simulate human-like thinking, enabling them to respond to problems proactively or reactively in a deliberate, intelligent, and adaptive way[2,3]. In a similar vein, Russell and Norvig, refers to Artificial Intelligence (AI) as the development of computer systems that can perform tasks typically requiring human intelligence, such as decision-making, speech recognition and visual perception[4]. In healthcare, AI is primarily employed in tasks such as data management, diagnostic assistance, treatment recommendations, and patient monitoring[1].

According to Davenport and Kalakota, AI in healthcare specifically refers to the use of advanced technologies and algorithms to replicate human cognition and decision-making in the analysis, interpretation and management of medical data[5]. One of AI's key strengths is its capacity to learn and recognize patterns and relationships from large, complex datasets. For example, AI can reduce a patient's entire medical history into a single metric, representing a likely diagnosis[6,7]. The most relevant branches of AI in health information management include machine learning (ML), which allows systems to learn from data patterns and natural

language processing (NLP), which enables the interpretation of human language in unstructured health records[8]. Through these technologies, AI is poised to improve the quality, speed and accessibility of healthcare data, particularly in resource-constrained settings like Nigeria.

METHODS

A scoping review of literature relating to AI, EMR and health data management.

RESULTS & DISCUSSION

Applications of AI in Health Data Management

The integration of Artificial Intelligence into healthcare has opened new avenues for enhancing patient care, optimizing healthcare operations and advancing public health initiatives. This section explores the application of AI across health data management.

Data Collection and Entry: Traditionally, data collection in healthcare has been manual, error-prone, and time-consuming. Artificial Intelligence tools, such as voice recognition software and electronic health records (EHR) systems powered by AI, now automate the process of data entry. These tools capture data in real-time, minimizing errors and ensuring that the data is structured for easier analysis[1]. For instance, speech-to-text AI systems allow healthcare providers to dictate patient information, which is then converted into structured records[9].

Data Storage and Security: AI also plays a crucial role in enhancing data security and management. Health data is highly sensitive and breaches can result in severe consequences for patients and healthcare providers. The AI-driven encryption systems can secure patient records and ensure that only authorized personnel have access. Furthermore, AI systems can monitor health data for anomalies, alerting authorities to potential security breaches or data corruption[10]. These AI tools also facilitate efficient data storage by organizing vast amounts of information, making it easily retrievable for future use.

Data Analysis and Prediction: One of AI's strongest capabilities is in predictive analytics. The AI systems analyze large datasets from patient's health records, research data and population health data to uncover patterns that can predict disease outbreaks, patient outcomes and treatment effectiveness[8]. For example, during the COVID-19 pandemic, AI was used to analyze public health data to predict outbreak patterns and resource needs[11]. This predictive capability allows health systems to preemptively respond to health crises and improve patient care.

AI in Decision Support Systems: AI-powered decision support systems assist clinicians by analyzing patient data and providing diagnostic recommendations or treatment plans based on historical data and clinical guidelines[12]. For instance, IBM's Watson Health uses AI to analyze medical literature and clinical trial data to offer oncologists evidence-based treatment options for cancer patients[12]. This reduces the cognitive load on healthcare providers and improves diagnostic accuracy.

Current Challenges and Risks of AI in Health Data Management

Despite the potentials of AI to revolutionize health data management, Nigeria faces several challenges:

Inadequate Infrastructure: Hasley opines that a significant barrier to the rapid advancement of AI technology in Africa is the inadequate infrastructure, exemplified by low Internet penetration (39%) and sociocultural challenges that hinder adoption[13]. Many healthcare facilities in Nigeria, lack technology infrastructure, particularly in rural areas, lack the necessary computers and computing technologies, internet access and electricity to support AI systems[14].

Additionally, widespread electricity inaccessibility is a pressing issue, with nearly half of the African population lacking reliable electricity access, complicating the execution and sustainability of digital initiatives across sectors, including

healthcare[15]. Research indicates that fewer than 30% of healthcare facilities on the continent have dependable electricity supplies[16]. Furthermore, the digital health infrastructure that could support various AI solutions is also found to be lacking[13].

Patient Data Protection: The effective use of AI in healthcare largely relies on accessing patient data such as health records, diagnostic scans and genetic details. While AI has the potential to improve healthcare outcomes, it also introduces significant concerns regarding data privacy. Protecting sensitive patient information is essential for maintaining trust and complying with legal frameworks such as the Health Insurance Portability and Accountability Act of 1996 (HIPAA). To safeguard this data, healthcare providers must implement strong security measures such as encryption, access control systems and routine audits. Ethical data management and strict compliance with privacy regulations are crucial to ensuring that AI technologies remain secure and respect patient confidentiality[5].

Data Breaches: The increasing inter-connectivity of healthcare systems and the growing reliance on electronic health records make healthcare providers more susceptible to cyberattacks and data breaches. These breaches can severely impact patient privacy, safety and public trust. The fallout from a breach could involve identity theft, fraudulent claims and even improper medical treatments. To mitigate these risks, healthcare organizations must adopt robust cybersecurity practices, conduct frequent system updates and train staff regularly. Having well-prepared incident response plans in place is equally important to swiftly handle breaches and minimize their damage[17].

Nigeria's current data protection laws are weak and healthcare institutions often struggle to protect sensitive patient information. As healthcare systems and providers transit to digital records, there is a risk of data breaches and misuse of personal health information[18]. Ensuring robust cybersecurity measures is essential for AI-driven health data systems.

Informed Consent: In AI-driven healthcare, obtaining informed consent from patients is critical, as it ensures they understand the implications of AI's role in their care. Due to the complexity of AI technologies, including intricate algorithms and vast datasets however, explaining these details to patients can be challenging. Healthcare providers need to focus on patient education and ensure transparent communication, offering accessible information on how AI will be used, its benefits and the protections in place for patient data. Ensuring patients are well-informed not only fosters trust but also ensures their autonomy and consent in AI-assisted care decisions[19].

Data Quality and Availability: The effectiveness of AI models heavily depends on the quality, completeness, and accuracy of the data used for training and analysis. Health data can be fragmented, incomplete, or inconsistent, especially in low-resource settings or regions without integrated electronic health records (EHRs). Poor data quality can limit the accuracy and reliability of AI systems, leading to incorrect predictions or diagnoses. This issue is particularly pronounced in datasets requiring medical expert annotations, which are often expensive and time-consuming to gather (Tran et al., 2019). Furthermore, the limited use of electronic medical records and low digitization rates across Africa result in a lack of locally generated data that are essential for developing effective AI systems[20].

Algorithmic Bias and Fairness: Another critical aspect to consider is algorithmic bias. AI algorithms are trained on historical data, which may contain biases based on gender, race, socioeconomic status, or geography. While this is a global concern, it poses a greater challenge in the African context[21]. These biases could lead to unequal treatment or inaccurate predictions for underrepresented populations. For example, an AI tool developed from a data-set dominated by patients from affluent regions may not perform as

well for patients from low-income areas. Managing bias to ensure fairness in AI-driven health decisions is critical. Additionally, biases inherent in the algorithms created by developers can lead to unintended discrimination and negative outcomes, when these systems are applied in low-resource settings without sufficient local input and data[22].

Legal and Policy Issues: Globally, numerous countries are in the process of developing governance policies and legal frameworks to oversee AI implementation across various sectors, including healthcare[23]. In Africa, several nations lack a national digital health policy or strategy to guide the implementation and monitoring of digital health initiatives. Stakeholders in Africa believe that increased government involvement at the policy level is crucial for encouraging the adoption of AI and other digital health technologies[24].

Currently, there are no established laws that delineate responsibility for any adverse outcomes that may arise from the use of AI in healthcare, which is a likely scenario given the contexts in which AI is employed. While existing laws may provide some guidance, many situations and applications remain unaddressed, potentially leading to legal repercussions for users and patients in various African nations[25].

Interoperability Issues: Health data is often stored in different formats across various healthcare systems, making it difficult to integrate data from multiple sources. The lack of standardized protocols for exchanging health information across platforms poses challenges for AI systems, as they require consistent, interoperable data streams to function optimally. Achieving data interoperability across diverse healthcare environments remains a complex issue.

Cost and Resources Barriers: Implementing AI systems in health data management can be expensive, requiring significant investments in technology, infrastructure, and staff training. For smaller healthcare facilities or those in low-resource settings, the financial and logistical barriers may hinder the adoption of AI, potentially widening the gap between resource-rich and resource-poor healthcare systems.

Integration into Workflow: Successfully integrating AI systems into existing healthcare workflows can be challenging. Artificial intelligence tools must be seamlessly embedded into clinical practice to be effective, yet many healthcare professionals struggle with incorporating new technologies into their day-to-day tasks. Ensuring AI systems are user-friendly and easily adoptable without disrupting clinical workflows is key to their long-term success.

Concerns about the Role of Human Judgment in Healthcare: While AI can process large datasets and identify patterns faster and more accurately than humans, there is concern that over-dependence on these systems could reduce the need for physicians to exercise their professional judgment and critical thinking. Topol highlights that although AI excels in tasks like image analysis, diagnosis and predictive analytics, it cannot consider the full range of human factors such as emotions, ethics, and individual patient contexts, that healthcare providers typically take into account[26]. This raises questions about how much trust should be placed in AI decisions and whether it could potentially erode the physician-patient relationship by reducing direct human interaction and empathy in care.

Furthermore, human oversight is essential, especially in situations, where AI systems may misinterpret data or make errors. Clinicians must remain actively involved to ensure AI-driven recommendations align with broader clinical assessments and ethical considerations, safeguarding against blind trust in AI technology.

Benefits of AI in Health Data Management

AI presents several benefits to Nigeria's health system, enabling it to meet the goals of sustainable development:

Improved Efficiency and Accuracy: By automating administrative tasks and data collection, AI reduces the burden on healthcare workers and minimizes human error[1]. This leads to more accurate health records, which are crucial for effective patient care and health management.

Enhanced Decision-Making: AI-powered systems analyze vast amounts of complex health data more efficiently than humans, identifying patterns and correlations that manual analysis may overlook. This enhances decision-making in clinical settings, enabling healthcare providers to make more informed, data-driven decisions regarding diagnoses, treatment plans, and patient management[8].

Better Resource Allocation: AI can be used to analyze population health data and predict healthcare needs, allowing health systems to allocate resources more effectively. For instance, AI can help forecast disease outbreaks, ensuring that hospitals are well-prepared[11].

Cost Reduction: AI's ability to streamline data processes and improve operational efficiency results in significant cost savings for health systems. This is particularly important for low-resource countries like Nigeria, where healthcare costs are a significant barrier to access[14].

Enhanced Diagnostic Accuracy: AI-driven diagnostic tools significantly improve the accuracy of diagnoses. By analyzing medical images, lab results, or patient data, AI systems can provide early and accurate diagnoses of diseases like cancer, diabetes, and heart conditions. These systems reduce human error and help in identifying health conditions earlier, leading to better patient outcomes[27,26].

Streamlined Administrative processes: In health data management, AI automates routine administrative tasks like appointment scheduling, billing, and claims processing. This reduces the administrative burden on healthcare staff, freeing up time for patient care. Automated data entry and record-keeping also enhance accuracy and reduce errors in patient documentation and financial transactions[12].

Faster and more Efficient Drug Discovery: AI algorithms accelerate the drug discovery process by analyzing massive datasets related to disease biology and chemical properties. Artificial Intelligence can predict the effectiveness of new drug compounds, reducing the time and cost involved in bringing new drugs to market, which is particularly beneficial during pandemics and other public health emergencies[28].

Personalized Medicine: AI enables personalized medicine by analyzing individual patient data, including genetic information, medical history, and lifestyle factors. This allows the development of customized treatme5.nt plans tailored to the unique needs of each patient, improving treatment efficacy and reducing adverse reactions, especially in areas like oncology and chronic disease management[29].

Predictive Analytics and Early Intervention: AI's predictive analytics capabilities allow for early detection of potential health risks based on patient data trends. AI can predict the likelihood of hospital readmission, the onset of chronic diseases, or disease outbreaks, enabling early intervention and reducing healthcare costs while improving patient outcomes[30].

Improved Data Management and Organization: AI efficiently organizes, structures and manages large volumes of health data from various sources, including EMR and EHRs and medical devices. This organized data is more accessible, shareable and easier to analyze, improving coordination of care and the effective use of health information across departments or healthcare providers[31].

Enhanced Patient Monitoring and Care: AI-powered tools such as wearable and health monitoring devices continuously track patients' vital signs in real time. AI analyzes this data to detect abnormalities or health risks and alerts

healthcare providers, when intervention is needed, improving patient care and treatment adjustments, especially for individuals with chronic conditions[29].

Reduction in Human Error: AI reduces the likelihood of human error in health data management, from diagnostic accuracy to data entry. Automation and decision-support systems help minimize mistakes, ensuring that patient data is processed accurately and medical errors related to treatment and documentation are reduced[31].

Efficient Resource Management: AI optimizes resource allocation in healthcare settings, predicting peak times for patient admissions and helping manage hospital bed availability, staffing needs and inventory control. This allows healthcare providers to allocate resources effectively and avoid shortages in critical care areas[8].

Case Studies: AI Revolutionizing Health Information Systems Globally

Countries around the world are adopting AI to revolutionize their health systems:

The United States: The United States has been at the forefront of AI adoption in healthcare. For example, hospitals use AI-powered diagnostic tools to assist radiologists in detecting diseases like cancer from medical images[26]. The integration of AI has led to faster and more accurate diagnostics.

The United Kingdom: The National Health Service (NHS) in the UK employs AI to predict patient admission rates, allowing hospitals to allocate resources efficiently. The system has improved patient care by reducing waiting times and ensuring that resources are available when needed[1].

India: In India, AI tools have been used to monitor and predict outbreaks of diseases like tuberculosis. These tools analyze population health data to identify high-risk areas, enabling targeted interventions[11].

Other African countries: Ubenwa is a start-up that leverages signal processing and machine learning to enhance the diagnosis of birth asphyxia in resource-limited settings, and also demonstrated the potential of AI in diagnosing diabetic retinopathy in Zambia, with promising and comparable results to human assessments[32]. The AI system exhibited clinically acceptable performance in identifying referable diabetic retinopathy[32]. Additionally, the Delft Institute's CAD4TB software has been used in pilot studies in Tanzania and Zambia to assist in diagnosing pulmonary tuberculosis through chest X-rays, with performance on par with human experts[33,34].

In Nigeria: AI has also made strides in Nigeria's pharmaceutical industry. In 2018, five high school girls gained international recognition by winning a Silicon Valley contest for developing an app, based on MIT open-source software, designed to detect counterfeit drugs[35]. In 2019, Adebayo Alonge, a Nigerian pharmacist, won the Hello Tomorrow Global Challenge grand prize for his AI-hyperspectral platform aimed at authenticating drugs[36]. Nigeria has a unique opportunity to leverage AI for health system transformation. By adopting AI, Nigeria can address its current challenges and move towards achieving universal health coverage. The integration of AI can also position Nigeria as a leader in health innovation in Africa.

Implementation Strategies for AI in Health Data Management in Nigeria

Infrastructure Development: Nigeria must invest in upgrading its healthcare infrastructure to support AI technology. This includes improving internet access, improving electricity supply, and purchasing AI-ready systems for hospitals and clinics[18]. These investments are crucial for ensuring that AI solutions can be implemented nationwide.

Capacity Building: HIM professionals and other healthcare workers need training in AI technologies and data management. Training programs should be integrated into medical and health management education to equip future professionals with the skills to operate AI systems[14].

Collaboration with Stakeholders: Successful AI implementation requires collaboration between governments, the private sector, academic institutions and international organizations. Public-private partnerships can provide the necessary funding and expertise to drive innovation in AI for healthcare[8].

Ethical Considerations: AI in healthcare raises several ethical concerns, including patient consent, algorithmic bias and data privacy[26]. Policy makers must develop regulations to ensure the ethical use of AI in health information systems, protecting patient rights while leveraging AI's benefits.

Policy and Practice Recommendations for Promoting AI Adoption and Regulation

To ensure the successful implementation of AI in health data management, Nigeria should:

Regulatory Frameworks: It is essential to establish strong and flexible regulatory frameworks to govern AI use in healthcare. These frameworks should provide comprehensive guidelines for the testing, validation and approval of AI systems. They must address the need for AI safety, efficiency, data privacy and ethical standards. As AI continues to evolve rapidly, the regulations should be adaptable to accommodate ongoing technological advancements, all while maintaining patient safety and protecting data security.

Incentives for Innovation: Governments and healthcare organizations should introduce incentives like research grants, tax breaks and funding programs to promote the development of AI technologies in healthcare. These incentives would stimulate research and development in AI solutions that enhance patient care and make healthcare systems more efficient. By providing financial support for innovation, such measures would encourage investments that yield economic and health benefits.

Patient Rights: Ensuring the protection of patient rights is a fundamental aspect of AI-driven healthcare. Policies should empower patients to control their data by allowing them access to their health information and granting them the ability to decide how their data is used. Patients should also be able to give or withdraw consent for AI-based treatments and have the right to data portability. Transparent policies that promote informed consent and patient autonomy are crucial for building trust in AI systems in healthcare.

Cross-Border Collaboration: Encouraging international collaboration on, AI regulation is key to fostering global standards and sharing best practices in healthcare. These technologies (AI's) transcend national borders, making it vital for countries to cooperate in creating harmonized regulations. Such international partnerships will facilitate the exchange of knowledge and experiences, allowing the development of ethical and responsible global guidelines for AI use in healthcare, benefiting both healthcare professionals and patients' worldwide.

CONCLUSION

Artificial Intelligence has the potential to revolutionize health information systems in Nigeria. By harnessing AI for better data management, Nigeria can improve healthcare delivery, reduce costs, enhance decision-making. While challenges remain, strategic investments in infrastructure, capacity building and collaboration can ensure that AI becomes a powerful tool for sustainable development in Nigeria's healthcare sector.

Recommendations
1. Invest in technological infrastructure and digital health systems.
2. Provide continuous education and training for healthcare professionals on AI

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Authors Contribution:

SN conceived of the study, initiated the design, participated in literature search, data abstraction and collection, analysis and coordination. AIT, IA, ARA, AA and MS participated in the design, literature search, records retrieval, technical process, data abstraction, data analysis and coordination and reviewed the final manuscript.

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