



Potential Impacts of Emerging Trends in Biomedical Research on Zimbabwe's Future Health Sector Development

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ABSTRACT:

Biomedical research in Zimbabwe is an expanding field, predominantly addressing region-specific health challenges such as HIV/AIDS, tuberculosis, malaria, and non-communicable diseases. This study explores the prospective influence of emerging biomedical technologies on the development of Zimbabwe's healthcare sector. While the societal benefits of research are often evaluated qualitatively rather than through economic metrics, historically, these contributions have been among the most significant in advancing public health. As human life expectancy continues to rise, policymakers and economists are increasingly concerned with the long-term social implications and escalating demand for healthcare services. The study employs exploratory desk-study and secondary research, assesses how emerging biomedical technologies could affect Zimbabwe's health sector. Its forward-looking, policy-oriented design synthesises existing knowledge to identify trends and propose strategic recommendations, relying solely on secondary data without primary collection. This investigation assesses how novel biomedical innovations such as artificial intelligence, machine learning, precision medicine, telemedicine, big data analytics, immunotherapies, biologics, point-of-care diagnostics, and the Internet of Things may impact Zimbabwe's health system. The integration of these technologies promises to enhance diagnostic accuracy, enable personalised treatment strategies, and foster more efficient, inclusive, and patient-centered healthcare delivery. This data-driven analysis aims to provide strategic insights into the adoption of emerging biomedical research trends, thereby informing future health sector development in Zimbabwe.

KEY WORDS: Emerging technologies, biomedical research, biomedical technologies & innovations, healthcare innovation, Zimbabwe healthcare.

1. INTRODUCTION

Biomedical research is fundamental to the advancement of global health, leading to significant improvements in diagnostics, treatment, and disease prevention. Scientific progress in this field has played a crucial role in extending life expectancy, reducing disease burden, and improving overall quality of life. According to Dattani et al. (2023), the global average life expectancy has more than doubled from 32 years in 1900 to 71 years in 2021. This transformation is largely attributed to innovations in biomedical science, which have led to better disease management, improved healthcare infrastructure, and the development of targeted treatment approaches. However, despite global progress, Zimbabwe continues to face significant healthcare challenges. The country experiences a high burden of both communicable and non-communicable diseases (NCDs), with the latter responsible for 39% of

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total deaths (WHO, 2023a,b). The under-five mortality rate remains high at 50 deaths per 1,000 live births (UNICEF DATA, 2024). These figures highlight the urgent need for effective biomedical interventions to improve healthcare outcomes.

The development and application of biomedical innovations have already demonstrated success in many parts of the world, particularly in high-income countries. For instance, artificial intelligence and machine learning have revolutionised diagnostics, allowing for rapid and accurate disease detection (Davenport & Kalakota, 2019). Similarly, genomics-driven precision medicine has enabled tailored treatments for complex diseases such as cancer, cardiovascular conditions, and diabetes (Hofker et al., 2014). Telemedicine has improved healthcare accessibility, particularly in rural and underserved areas, by enabling remote consultations and digital health monitoring (Chinene et al., 2023). The adoption of these technologies in Zimbabwe, however, remains limited due to infrastructural deficiencies, financial constraints, and inadequate human resources.

A crucial factor impeding biomedical advancements in Zimbabwe is the limited research and development (R&D) investment. Biomedical research in low and middle income countries (LMICs) has historically focused on communicable diseases such as malaria and HIV, often receiving external funding from global health organisations (Amankwah-Amoah, 2016). However, the epidemiological landscape is shifting, with NCDs now representing a significant health threat in LMICs, including Zimbabwe. Addressing this challenge requires a paradigm shift in research priorities, with greater emphasis on innovative approaches.

To fully realise the benefits of emerging biomedical technologies, Zimbabwe must address several critical barriers. Zimbabwe, faces numerous challenges, including fragmented healthcare infrastructure, data privacy concerns, limited technical expertise, digital connectivity and funding for biomedical research and innovations (Muhunzi et al., 2024). Fostering collaborations between government agencies, academic institutions, and private sector stakeholders is critical to drive biomedical research, innovations and technologies. Capacity-building initiatives, such as training healthcare professionals in genomics and AI-driven diagnostics, will also be essential in ensuring the successful integration of these innovations into the healthcare system (We Need a Genomics-Savvy Healthcare Workforce, 2023).

Investing in robust digital health infrastructure is essential to harness its full potential in the healthcare system. Potentially scaling up biomedical innovations and technologies could significantly improve healthcare delivery, particularly in rural areas where access to medical facilities is limited. In this study, we explore the latest advancements in biomedical research and assess their potential impact on Zimbabwe's healthcare system. By examining these emerging trends, we aim to provide insights into how these technologies can be effectively implemented to improve health outcomes and bridge existing gaps in the country's medical landscape.

2. METHODOLOGY

2.1 Literature Review

A systematic review of recent (2015–2025) peer-reviewed articles, reports, and white papers on emerging biomedical technologies was conducted. Technologies of focus included: Artificial Intelligence and Machine Learning; Precision Medicine and Genomics; Telemedicine and Teleradiology; Point-of-Care Diagnostics; Immunotherapy and Biologics; Big Data Analytics in Healthcare and Internet of Things (IoT) in Healthcare. Sources included academic databases (PubMed, Google Scholar), institutional reports (WHO, UNICEF, MoHCC), and technology case studies from both developed and developing contexts.

2.2 Analysis of Zimbabwe's health sector in context

An analysis of Zimbabwe's current health infrastructure, disease burden, and policy landscape was performed using: national and international health statistics (WHO, UNICEF, MoHCC); reports on healthcare access, workforce distribution, and digital readiness. Identification of key challenges: rural medical care, medical health insurance, funding constraints, personnel turn over, and infrastructural deficits.

2.3 Mapping technology to impact

Each emerging technology was systematically evaluated based on its relevance to national health priorities, feasibility within local constraints, and potential impacts on access, efficacy, and system resilience in Zimbabwe.

2.4 Analysis of Stakeholders and Policy Frameworks

A comprehensive stakeholder analysis identified key actors including government bodies, academic institutions, and international partners. This was complemented by a review of existing national digital health and research policies. The process highlighted critical gaps in governance, funding, training, and infrastructure, which directly informed the subsequent strategic recommendations.

2.5 Synthesis and Recommendation Development

The integrated findings from all phases were synthesised to construct a coherent narrative on biomedical technologies' transformative potential for Zimbabwe. This synthesis directly informed evidence-based strategic recommendations focused on critical areas: digital and genomic infrastructure investment, workforce capacity building, supportive policy frameworks, and fostering public-private and international collaboration.

3. EMERGING BIOMEDICAL TECHNOLOGIES

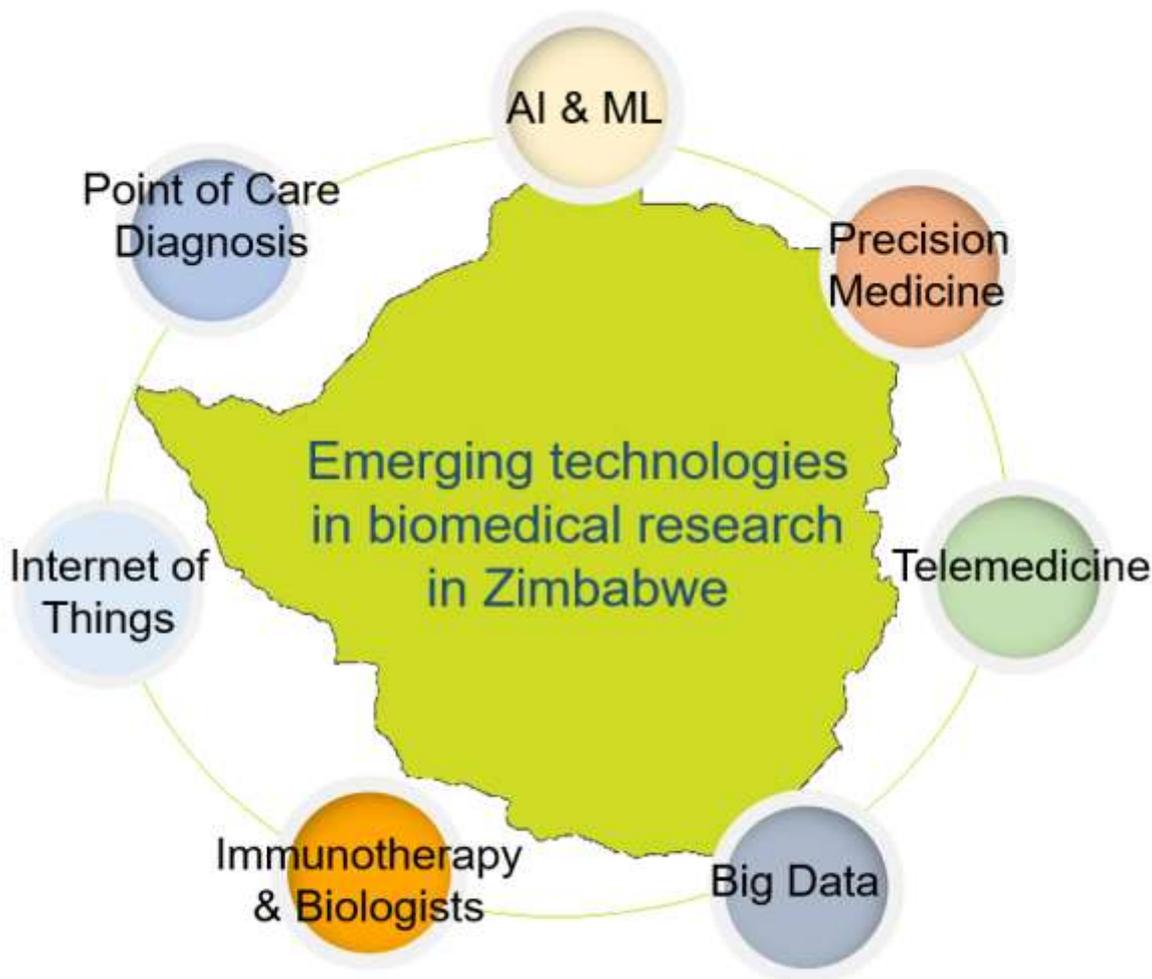


Figure 1: Illustrates the potential emerging technologies that can be adopted in biomedical research in Zimbabwe.

3.1 Artificial intelligence and machine learning

Artificial intelligence (AI) encompasses computer systems that possess the ability to perform intricate tasks, traditionally attributed to humans, such as decision-making and problem-solving. The application of AI in healthcare is gaining momentum and holds immense potential to revolutionise patient care and streamline administrative processes (Davenport & Kalakota 2019). A significant portion of medical diagnoses relies on the analysis of disease images acquired through advanced digital devices. AI techniques like Machine Learning (ML) and Deep Learning (DL) are extensively employed in the prediction and diagnosis of numerous diseases that rely on imaging-based diagnostic approaches (Uysal & Ozturk 2020). Due to inadequate remuneration, Zimbabwe is witnessing a significant outflow of essential medical professionals, including radiographers and medical doctors, to developed countries. Application of AI systems in hospitals can reduce the impact of lack of radiographers as AI can be used to accurately analyse medical imaging, such as X-rays, CT scans and MRIs (CWRU, 2024). Zimbabwe's maternal mortality ratio is at 462 deaths per 100,000 live births, while the neonatal mortality rate stands at 32 deaths per 1,000 live births (WHO, 2020).

Limited access to diagnostic tools, such as ultrasound during pregnancy, is the primary factor contributing to the high rates of maternal and neonatal mortality. Zimbabwe, being a developing country, faces constraints in terms of healthcare professional availability, medical technology, and resources. Introducing AI into healthcare systems can offer a disruptive approach to address these significant challenges. Several companies such as Butterfly Network and Exo have developed portable handheld ultrasound machines powered by AI. The innovative devices utilise AI algorithms to deliver enhanced accuracy and efficiency in diagnostic procedures (Whooley, 2024). The device employs AI technology to capture high-quality scans while a clinician moves the probe across a patient's body. It can be connected to a smartphone, enabling real-time viewing of the images. Handheld ultrasounds are user-friendly and do not necessitate the presence of a radiographer for operation. The ultrasound system has various other AI tools that analyse the scans in real time. These tools will provide calculations and assessments to assist in promptly prioritising potential health concerns. It is cheap and portable making it suitable for hospitals and clinics in low-resource settings in Zimbabwe.

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3.2 Precision medicine

Genomics, a field in biomedical science, has revolutionised healthcare through precision medicine. Historically, doctors have traditionally relied on the responses of the average patient to shape their recommendations regarding disease prevention and treatment. While this approach proves effective for the majority of patients and conditions, it may not yield the same results for others (CWRU, 2024). The publication of the human genome has enabled the characterization of diseases at the genetic level, facilitating the identification of novel genetic variants associated with various complex diseases (Hofker, 2014). Complex diseases include cardiovascular diseases, cancer, type 2 diabetes, autoimmune diseases and Alzheimer's diseases. These diseases cannot be treated effectively using standardised treatments. Complex diseases arise from the interplay of multiple genetic and environmental factors, contributing to their manifestation and development (Virolainen et al., 2023). Therefore, precision medicine becomes crucial to accurately assess an individual's susceptibility to diseases by considering their unique genetic and environmental factors, enabling informed decisions regarding effective interventions for disease prevention and treatment.

Precision medicine is an innovative approach that is based on the distinct factors influencing human health, including patients' genes, environments, and lifestyles. Precision medicine utilises the analysis of a patient's DNA to tailor treatments according to their specific requirements. It relies on the utilisation of data, analytics, and information. While precision medicine has gained prominence in developed countries, its application in developing nations is equally important due to the rise in complex diseases such as cancer and hypertension. To establish precision medicine sustainably in Zimbabwe, it is necessary to coordinate the efforts of various stakeholders and establish the required infrastructure.

The stakeholders involved in precision medicine include the government, which acts as the primary sponsor of research and development, as well as regulators, hospitals, and universities engaged in precision medicine research (Ginsburg & Phillips, 2018). The field of genomics and bioinformatics plays a vital role in the advancement of personalised medicine, as it allows for a deeper understanding of individual genetic variations and their impact on health. Consequently, it becomes imperative for the government to make substantial investments in genomics infrastructure and education. Investing in genomics infrastructure entails establishing state-of-the-art laboratories equipped with advanced genomic sequencing technologies and data storage capabilities (Owolabi et al., 2023). These resources are essential for efficiently analysing and interpreting vast amounts of genomic data. Additionally, developing robust bioinformatics tools and computational platforms is crucial to handle the complex data generated from genomic studies.

Government initiatives should focus on promoting genomics education at various levels, including universities, medical schools, and research institutions. Through building a workforce with a strong foundation in genomics, healthcare professionals and researchers will be better equipped to integrate genomic information into clinical practice and research (Crellin et al., 2019; We Need a Genomics-Savvy Healthcare Workforce, 2023). Investing in genomics infrastructure and education can lead to long-term benefits. It facilitates the identification of disease-specific genetic markers, enabling more accurate diagnoses and targeted treatment options for patients (NHS England, 2022). It also lays the foundation for the development of population-wide genomic databases, through collection of genomic data from diverse populations within Zimbabwe. This will help build a comprehensive genetic database that reflects the country's unique genetic makeup and enables more precise treatment approaches.

3.3 Telemedicine

Telemedicine refers to the provision of healthcare services remotely using the telecommunications infrastructure. Telemedicine in Zimbabwe plays a significant role in enhancing access to healthcare services, particularly in remote and underserved areas. As a developing country with geographical challenges and limited healthcare infrastructure, the implementation of telemedicine offers a viable solution to bridge the gap between patients and healthcare providers. By leveraging technology such as video consultations, remote monitoring devices, and mobile health applications, individuals across Zimbabwe can receive timely medical advice, diagnosis, and treatment without the need for physical visits to healthcare facilities. This not only improves the overall quality of healthcare but also increases efficiency and reduces healthcare costs for both patients and providers.

In Zimbabwe, telemedicine in radiology, also known as teleradiology, is gaining traction. This technological advancement enables radiologists and medical imaging experts to interpret images and offer diagnoses from a remote location, delivering essential healthcare services where they are needed most, especially in remote and underserved regions. While the benefits of telemedicine are evident, there are challenges to overcome, including infrastructure constraints, connectivity issues, and the need for comprehensive regulatory frameworks to ensure the efficient and secure delivery of radiological services. Despite these obstacles, the growing adoption of telemedicine in radiology promises to revolutionise the way healthcare is provided in Zimbabwe, opening up new possibilities for healthcare access and delivery in the country. In order to establish a successful and streamlined telemedicine system in Zimbabwe, it is crucial for the government to prioritise investments in ICT infrastructure, as it forms the fundamental framework of telemedicine (Chinene et al., 2023).

3.4 Point of Care Diagnostics

Incorporating point-of-care diagnostics into routine healthcare practices has greatly enhanced clinicians' ability to effectively care for patients with infectious diseases such as malaria, STIs, and tuberculosis in resource-limited settings worldwide (DeLuca et al.,

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2018). Point of care diagnostics allow clinicians to rapidly and accurately diagnose these diseases, enabling timely initiation of appropriate treatments and interventions. Zimbabwe has made a considerable progress in point of care HIV birth testing. A study conducted from November 2018 to July 2019 found that 98.3% of eligible HIV exposed infants received point of care HIV birth testing (Aitcheson et al., 2024). This high uptake ensures early identification of HIV-positive infants, allowing for timely intervention. Nevertheless, there is still a need for investment in point-of-care diagnostics for other diseases. The majority (61.4%) of Zimbabwe population is located in rural areas (UNICEF, 2022). Zimbabwe rural areas face pronounced healthcare service deficits, making it challenging for residents to obtain the necessary medical care and support they need.

The health care deficits include timely diagnostics of diseases such as STIs, complex diseases and clinicians. Zimbabwe, like any developing nation, bears a heavy burden of infectious diseases such as malaria, schistosomiasis, cholera, AIDS, and tuberculosis. Given the significant prevalence of these diseases, the availability of point-of-care testing (POCT) devices is considerably limited. Currently Zimbabwe lacks a definitively approved rapid diagnostic testing tool for point-of-care testing of intestinal schistosomiasis. Thus, Zimbabwe is unable to conduct test and treat bilharzia at the point of care (Gwarisa, 2023). This limitation hampers the country's ability to conduct surveillance since there are currently no available means for surveillance of intestinal schistosomiasis in place. There is a pressing need for the research and development of newer, advanced, reliable, and user-friendly point-of-care medical devices that are affordable and require low maintenance (Mitra & Sharma, 2021).

Investing in point-of-care diagnostics will revolutionise healthcare delivery in Zimbabwe by improving early detection, reducing underdiagnosis, and enhancing patient management. These initiatives contribute to better health outcomes for individuals and communities.

3.5 Immunotherapy and Biologics

Immunotherapy is a novel treatment approach to advanced cancer that targets or manipulates the immune system to combat disease without harming normal cells. Immunotherapy is often used in combination with other conventional approaches such as chemotherapy and radiotherapy. Despite its novelty and promising results in terms of survival benefits, the use of immunotherapy in developing countries is limited mainly due to its cost and lack of immune-oncologists (Akl et al., 2020). In Zimbabwe the exorbitant costs associated with cancer medications present challenges for both public and private healthcare systems in providing patients with the latest treatment options. Significant emphasis in cancer research has been placed on populations of European descent, resulting in a scarcity of comprehensive data pertaining to African populations. Consequently, there is a pressing need to establish dedicated cancer research facilities in Zimbabwe, specifically tailored to address the unique healthcare challenges and genetic profiles of the local population. By doing so, these facilities can develop targeted and effective solutions that are specifically suited to the needs of the Zimbabwean populations, ensuring improved outcomes and advancing the field of oncology in the country. The financial burden of immunotherapy on cancer patients can be alleviated by shifting the burden to the governmental institutions and health care system (Akl et al., 2020). Implementing a screening process for predictive biomarkers becomes crucial to ensure that immunotherapy is administered to patients who have demonstrated optimal results. Identifying these predictive biomarkers holds immense significance as it enables the selection of patients who are most likely to benefit from the treatment, optimising outcomes and resource allocation (Sankar et al., 2022). The establishment of immunotherapy in Zimbabwe offers a valuable alternative for treating cancers that display resistance to surgery and chemotherapy, particularly in cases where existing cancer treatment drugs prove to be costly. Immunotherapies can be more cost-effective than traditional treatments like surgery and chemotherapy. However, introducing immunotherapy requires investment in research, training, and infrastructure. It's a step toward more equitable and effective healthcare system in Zimbabwe.

3.6 Big Data

Big data in healthcare is the use of digital technology to create and analyse large volumes of data related to patients, treatments, and outcomes. Healthcare is abundant with valuable data that is generated from various sources such as electronic medical records, medical imaging technology, wearables, clinical notes, administrative databases, clinical databases, electronic and laboratory information systems (Auffray et al., 2016, Muhunzi et al., 2024). Other sources also include biometric data, data from social media, biomarker data from genomics, pharmacogenomics and proteomics. This data can be used by government or managers for decision making process (Cozzoli et al., 2022). However, due to its high complexity and heterogeneity, big data cannot be effectively managed using traditional software or hardware, nor can it be easily handled with conventional data management tools and techniques (Ristevski & Chen, 2018, Muhunzi et al., 2024). The implementation of big data analytics requires extensive computational resources such as cloud computing to support the processing and storage of large datasets (Cremin et al., 2022)

Big data is primarily utilised in developed nations due to their well-developed internet infrastructure, digitalised healthcare systems, and centralised data repositories, enabling the implementation of big data analytics (Song and Ryu, 2015, Colombo et al., 2020). Zimbabwe and other developing nations, as a whole, have not yet implemented big data analytics at the government level. Instead, it is predominantly implemented by private healthcare institutions. Zimbabwe faces threats from both non-communicable diseases and communicable diseases, including bilharzia, malaria, sexually transmitted infections (STIs), and cholera. A study by Amankwah-Amoah (2016) investigates the utilisation of big data to address health challenges, particularly during the Ebola outbreak

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in West Africa. Implementation of big data analytics in health care in Zimbabwe can significantly contribute to disease surveillance and support informed decision-making in combating the spread of these diseases.

Disease surveillance, predictive analytics and population health management and the identification of high-risk populations in Zimbabwe are hindered by data silos and lack of seamless digital infrastructure for healthcare. Zimbabwe's health sector is fraught with ethical, regulatory, security concerns and technological challenges when it comes to collecting information from individuals, which is a prerequisite for any big data approach (Muhunzi et al., 2024). In order to facilitate effective data collection, it is necessary to establish interoperable information systems that are built upon standardised frameworks. The government should prioritise the digitisation of all clinical exams and medical records within the healthcare systems. To establish a big data infrastructure, the government should establish a national medical big data repository to collate health data. The big data repository will receive data from various sources such as electronic health records, public health record, clinical data, sensing data, and omics data. The acquired data can then be utilised, through data analytics (descriptive, diagnostic, predictive and prescriptive) to give smarter and cost effective decisions (Dash et al., 2019).

An appropriate governance framework must be developed and enforced to protect individuals and ensure that health-care delivery is tailored to the characteristics and values of the target communities. The impacts of big data in Zimbabwe's health care is vast. It includes medical image processing and analysis, enhanced precision medicine, real time patient monitoring, predictive analytics and population health management, healthcare fraud detection, accurate treatment outcome assessment, streamlined clinical research and efficient resource allocation (Soni, 2023).

3.7 Internet of things

The Internet of Things (IoT) in healthcare refers to the use of smart devices and systems that can monitor, communicate and deliver health-related data and services without requiring human-to-human or human-to-computer interaction (Kelly et al., 2020, Ryalat et al., 2023). In developed nations, IoT technologies are currently being utilised in healthcare to enhance patient care and improve outcomes through remote monitoring (Alshammari, 2023) and personalised treatment plans (Tiwari et al., 2023). Data is constantly collected, and communicated from patient by intelligent devices such as wearables, cameras and medical devices. The data is stored, which becomes possible to leverage data analytics and smart healthcare capabilities. This leads to improved identification of risk factors, disease diagnoses, treatment options, remote monitoring, and empowers individuals to take charge of self-management (Kelly et al., 2020).

Although IoT technology is already being utilised, its implementation remains limited in scale and primarily confined to private hospitals. Expanding the utilisation of IoT technology in all hospitals presents numerous opportunities and possibilities that can significantly enhance healthcare in Zimbabwe. For security purposes, the technology is used to monitor the assets of the hospital such as medical equipment. For this potential to be realised fully, it is crucial to have secure and reliable communication infrastructure with sufficient bandwidth dedicated to healthcare. The integration of IoT technology in Zimbabwe's health sector will lead to improved management of drugs and equipment, reduced errors in healthcare operations, accurate data-driven treatment of patients, speedy disease diagnosis, and enhanced patient surveillance even in rural areas.

CONCLUSION

This study has shown that the impact of emerging biomedical technologies on the Zimbabwe health sector is substantial. The integration of these emerging technologies in biomedical sciences has the potential to transform the Zimbabwe health sector by improving healthcare access, enhancing diagnostic capabilities, enabling personalised treatment approaches, and optimising healthcare resource utilisation. However, successful implementation requires a comprehensive approach that addresses infrastructure challenges, regulatory frameworks, data privacy and security concerns, and healthcare workforce training. The primary objective of the study is to shape policy decisions regarding the integration of emerging technologies, aiming to enhance healthcare delivery for the Zimbabwean population. The study can also aid policy developers in acknowledging the potential of emerging technologies to enhance health equity by facilitating connectivity between underserved populations in rural areas and urban health facilities staffed by highly qualified personnel. Embracing these technologies and addressing the associated challenges, Zimbabwe can unlock the full potential of emerging technologies and advance its healthcare system to benefit patients and healthcare providers alike.

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