Fighting Resistance With Data: Leveraging Digital Surveillance to Address Antibiotic Misuse in Nigeria

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Abstract. Antimicrobial resistance (AMR) represents a growing public health challenge in Nigeria. The pervasive misuse of antibiotics, insufficient regulatory frameworks, and inadequate surveillance systems exacerbate this issue. The existing methods for antibiotic monitoring are fragmented and inefficient, hindering the ability to detect real-time resistance patterns. This review delves into the role of digital surveillance technologies in combating AMR, taking advantage of electronic medical records (EMRs), mobile health (mHealth) applications, AI-powered analytics, and cloud-based databases to enhance data collection, prescription tracking, and policy interventions. Research conducted in low- and middle-income countries (LMICs), including India and Kenya, demonstrates digital tools' efficacy in addressing antimicrobial resistance (AMR). Despite these advantages, Nigeria continues to face significant challenges related to data privacy, infrastructure limitations, financial sustainability, and a digital divide between urban and rural regions. Addressing these limitations requires implementing strategic investments in health technology, establishing robust regulatory frameworks, and fostering multi-sectoral collaboration among government agencies, private sector stakeholders, healthcare institutions, and research organisations. In this review, we strongly advocate for an approach that integrates a data-driven antimicrobial resistance (AMR) surveillance system, facilitating real-time monitoring and policy-driven strategies. Nigeria can enhance antibiotic

INTRODUCTION

Antibiotic resistance represents a significant global health challenge, particularly impacting low- and middle-income countries like Nigeria. The misuse and overuse of antibiotics in Nigeria have led to the emergence of resistant bacterial strains, complicating the treatment of infections that were once easily treatable [1]. This issue is exacerbated by inadequate enforcement of antibiotic regulations, insufficient surveillance, and a fragile healthcare infrastructure. If unaddressed, antibiotic resistance may result in prolonged hospital stays, increased mortality rates, and a heightened financial burden on patients and the healthcare system [2]. A primary contributor to antibiotic resistance in Nigeria is the widespread availability of antibiotics without prescription. Many individuals engage in self-medication, often with incorrect dosages or inadequate treatment regimens [2].

Moreover, inappropriate prescribing practices by healthcare professionals, such as the excessive use of broad-spectrum antibiotics, contribute to developing resistance. The absence of stringent regulations and enforcement mechanisms prevents these practices from persisting, thereby complicating efforts to control antibiotic overuse effectively [3]. Nigeria urgently requires a reliable, real-time monitoring system to track antibiotic use, detect resistance tendencies, and guide policy measures to confront this expanding epidemic. Traditional monitoring approaches are frequently slow, fragmented, and inconsistent, rendering them useless in combating the dynamic nature of antibiotic abuse [1, 4]. A more proactive strategy is essential to prevent the spread of resistance before it becomes unmanageable [5].

Digital health technologies offer a promising avenue for advancement. Digital surveillance, incorporating electronic health records, pharmacy tracking systems, and artificial intelligence, can provide real-time data on antibiotic prescriptions and usage patterns [6]. These tools can assist in identifying usage hotspots, alerting authorities to growing resistance tendencies, and facilitating evidence-based decision-making. Implementing digital health solutions in Nigeria could be a game-changer in the fight against antibiotic re-

sistance, ensuring a more long-term and effective response to this public health issue [1, 7].

RESULTS AND DISCUSSION

Understanding Antibiotic Misuse and Resistance in Nigeria. Antibiotic resistance is a significant public health concern in Nigeria, caused by widespread antibiotic abuse. According to the World Health Organization (WHO), Nigeria has one of the highest incidences of antimicrobial resistance (AMR) in Africa [8]. A 2019 survey discovered that more than 88% of Nigerians had used antibiotics without a prescription, contributing to the growth of resistant bacterial diseases [2]. Furthermore, hospital data from large cities such as Lagos and Abuja show that more than half of bacterial illnesses no longer respond to first-line antibiotics, requiring healthcare practitioners to turn to more expensive and less accessible alternatives [9].

Specific populations are more susceptible to antibiotic overuse and the implications of resistance. Rural areas with limited access to skilled healthcare providers sometimes rely on patent medicine merchants to sell antibiotics without sufficient instruction [10]. Many people in urban slums practice self-medication, acquiring antibiotics from open markets or illicit medicine suppliers. Furthermore, hospitalised patients, particularly those in intensive care units (ICUs), are at a higher risk of developing multidrug-resistant infections due to extended antibiotic exposure. Children, pregnant women, and people with chronic conditions are particularly vulnerable to antibiotic resistance [11].

One of Nigeria's most significant challenges in addressing antibiotic resistance is the lack of reliable data. Traditional methods for monitoring antibiotic usage and resistance rely on handwritten documentation, which is often incomplete and unreliable [1, 8]. Many healthcare facilities use paper records, leading to fragmented reporting across states and regions. The absence of a unified national database hinders the real-time detection of resistance patterns, resulting in delays in treatments that could prevent resistant disease outbreaks [12]. Without accurate data,

authorities face difficulties implementing effective policies and guidelines to combat antibiotic overuse [13].

Several real-world instances demonstrate these problems. Research conducted at a tertiary hospital in Lagos discovered that approximately 70% of antibiotic prescriptions were issued without laboratory confirmation of bacterial illnesses, resulting in needless drug exposure [14]. In a rural health clinic in northern Nigeria, medical staff observed that most patients requested antibiotics by name, influenced by previous experiences or non-medical advice. Due to a lack of an electronic tracking system, these facilities struggled to monitor prescription trends, making rational antibiotic use difficult to enforce [15].

Nigeria must establish a more efficient monitoring system capable of collecting real-time data on antibiotic usage and resistance patterns to combat antibiotic resistance effectively. Addressing the deficiencies in traditional data collection methods will be crucial for implementing targeted treatments and mitigating the increasing burden of antibiotic-resistant diseases nationwide [1, 11].

The Role of Surveillance in Combating AMR. Surveillance is crucial in combating antimicrobial resistance (AMR) because it identifies trends, guides policy decisions, and allows early action. A well-organised surveillance system aids in tracking antibiotic consumption, monitoring resistance tendencies, and assessing regulatory measures' efficacy [16]. Without real-time data, governments and health organisations are hindered in their ability to formulate targeted interventions, leading to the unchecked overuse of antibiotics and the proliferation of resistant bacterial strains. Informed decision-making, supported by comprehensive surveillance, is essential for preserving the effectiveness of current antibiotics and ensuring sustainable healthcare outcomes [17].

The World Health Organization's Global Antimicrobial Resistance and Use Surveillance System (GLASS) establishes a standardised framework for countries to gather and analyse AMR data. Nigeria has formally joined GLASS to improve its AMR monitoring skills and match its surveillance efforts with worldwide best practices [18]. This program has helped to increase laboratory capacity, share data, and implement national action plans to combat antibiotic misuse. GLASS provides Nigeria with access to a global network of AMR data, enabling comparative research and the implementation of proven intervention measures [19]. Despite its participation, the country has substantial barriers to completely incorporating GLASS-recommended practices into its healthcare system [20].

Current methodologies for tracking antibiotic usage in Nigeria are inadequate due to systemic deficiencies in data collection, infrastructure, and enforcement mechanisms. The country's antimicrobial resistance (AMR) surveillance predominantly relies on hospital-based data, with minimal integration of information from pharmacies, private clinics, and informal drug markets, where most antibiotic misuse occurs [1]. Many healthcare facilities continue to employ manual reporting systems, resulting in inconsistencies and delays in data collection. Additionally, laboratory capacity is unevenly distributed, with rural and underfunded hospitals lacking the necessary diagnostic tools to identify resistant pathogens effectively [21].

Furthermore, the lack of a national electronic prescription and distribution system impedes efforts to track antibiotic utilisation. While some tertiary institutions have implemented digital health records, most healthcare practitioners lack access to electronic monitoring systems, particularly those in primary care settings. This fragmented surveillance network limits a thorough picture of national antibiotic use trends, limiting the ability to adopt timely interventions [22].

Nigeria must invest in national digital surveillance infrastructure to remedy these gaps, expand laboratory networks, and implement rules requiring standardised antibiotic reporting across all healthcare sectors [23]. Without a coordinated and data-driven strategy, AMR will continue to endanger public health and degrade the efficacy of life-saving medicines [24].

Digital Surveillance Technologies: Global Lessons and Local Applications. Digital surveillance tools revolutionise healthcare by giving real-time data on antibiotic use and resistance tendencies. In the fight against antimicrobial resistance (AMR), these technologies improve data collection, streamline reporting, and allow for evidence-based policymaking. Adopting digital health tools can help Nigeria bridge gaps in traditional surveillance, resulting in a more proactive strategy for addressing antibiotic overuse [25].

Several digital health tools are essential for AMR surveillance:

1) EHRs allow healthcare practitioners to monitor antibiotic consumption patterns and report problematic prescriptions [26].

2) Mobile reporting systems enable healthcare professionals in remote places to record antibiotic use and resistance in real time [26].

3) Cloud-Based Databases: Nationally connected platforms consolidate healthcare data for policymakers and academics to access smoothly [26].

4) AI-powered analysis uses massive datasets to anticipate resistance patterns, identify high-risk areas, and recommend targeted actions [26].

Successful Case Studies from Other LMICs. Low- and middle-income countries (LMICs) have effectively used digital monitoring technology to prevent AMR, providing valuable lessons for Nigeria.

The National AMR Surveillance Network (NARS-Net) in India uses hospital-based electronic reporting systems and cloud databases to monitor antibiotic resistance nationwide. AI-powered analytics can forecast outbreaks, allowing timely policy actions [27].

Kenya's mHealth Platforms allow healthcare personnel to input real-time AMR data from remote clinics. These systems and AI-powered dashboards have enabled the early detection of resistance patterns [28]. Thailand's AMR Surveillance System integrates digital prescription tracking with national health records, minimising antibiotic usage in public and private healthcare institutions [29].

Examples of Nigerian Platforms. Nigeria has begun to integrate digital health technologies, albeit execution is inconsistent. Promising platforms include mHealth initiatives, such as the mDoc platform, which allows healthcare staff to record and track antibiotic prescriptions digitally [30].

a) Nigerian companies are building smartphone apps for drug monitoring, enabling pharmacists and physicians to report antibiotic sales and prevent illicit dispensing [30].

b) Nigeria's National Health Management Information System (NHMIS) is integrating digital reporting for illness surveillance. While now focused on infectious disorders, expanding to incorporate drug tracking has the potential to improve AMR monitoring significantly [30].

Challenges in Implementation. Despite the potential for digital surveillance, numerous constraints prevent widespread implementation in Nigeria:

a) Limited internet access in rural healthcare facilities reduces the effectiveness of cloud-based and mobile reporting technologies. Expanding the internet infrastructure is critical for national digital surveillance [30].

b) Many healthcare providers, especially in public hospitals and rural areas, lack basic training to use digital health tools. Without adequate training programs, the adoption of EHRs and AI-powered analytics will be delayed [30].

c) Funding constraints: The high cost of developing and sustaining digital health infrastructure presents a substantial challenge. Nigeria requires investment from the public and private sectors to build and deploy these technologies.

d) Regulatory and policy barriers: Although digital health policies exist, there is no national strategy for AMR surveillance. Setting explicit norms for data exchange, privacy, and interoperability is critical.

Nigeria can improve AMR surveillance and minimise antibiotic abuse by learning from other LMICs and increasing its digital health initiatives. Overcoming implementation obstacles requires collaborative efforts from government agencies, private health-tech businesses, and international partners. Investing in digital surveillance is more than a technological update; it is a key step toward protecting public health from the growing threat of antibiotic resistance [31].

Opportunities for Integrating Digital Surveillance in Nigeria. Incorporating digital monitoring technology into Nigeria's healthcare system represents a critical opportunity to combat antibiotic resistance. Nigeria may develop an effective surveillance system by leveraging public-private partnerships, improving engagement with pharmacy networks and hospitals, extending mobile-based community health tools, and implementing real-time dashboards for policymakers [23]. Furthermore, research institutions and universities can be important in promoting innovation and policy development.

Public-Private Partnerships. Collaboration among the government, corporate sector, and non-governmental organisations (NGOs) can hasten the implementation of digital surveillance [23]. Private health technology companies can help

create electronic health record (EHR) systems, AI-powered analytics, and cloud-based platforms for AMR tracking. International institutions, such as the World Health Organization (WHO) and the Africa Centres for Disease Control and Prevention (Africa CDC), can provide financial and technical support to help scale these solutions. Public-private partnerships can also encourage investment in digital infrastructure, ensuring that surveillance technologies reach underserved areas where antibiotic abuse is common [32].

Integration with Pharmacy Networks and Hospitals. Community pharmacies constitute significant stakeholders in Nigeria's antibiotic supply chain; however, many operate outside established regulatory frameworks. The integration of digital surveillance with pharmacy networks could facilitate the tracking of antibiotic sales and prescription patterns. Implementing a national digital prescription system, interconnected with pharmacies and hospitals, would enable real-time monitoring of antibiotic dispensing, thereby reducing illicit sales. Hospitals, particularly tertiary and teaching institutions, can employ AI-powered surveillance to identify resistance trends and contribute the findings to a national AMR dashboard [33].

Mobile-Based Community Health Reporting Tools. Given Nigeria's sizable informal healthcare sector, mobile-based surveillance techniques can help bridge the gap between formal and informal practitioners. Community health workers and patent medicine dealers frequently serve as patients' first point of contact and can use mobile apps to report antibiotic sales and suspected resistance cases [34]. Similar approaches have been successfully deployed in Kenya and Uganda, where mobile reporting systems offer critical real-time data to national health authorities. By providing user-friendly digital tools to frontline healthcare workers, Nigeria can improve the reach and accuracy of AMR surveillance [35].

Real-Time Dashboards for Policymakers. Data must be readily available and actionable for digital surveillance to be effective. A consolidated AMR dashboard integrating data from hospitals, pharmacies, and mobile health reporting technologies can give policymakers real-time information about antibiotic use and resistance patterns [36]. This method would enable the Nigerian Centre for Disease Control (NCDC) and the Federal Ministry of Health to respond swiftly to growing resistance threats. Policymakers might also employ predictive analytics to launch targeted initiatives in high-risk areas, resulting in a more proactive approach to AMR containment [34].

The Role of Research Institutions and Universities. Nigerian universities and research institutes are critical in improving AMR surveillance through data analysis, innovation, and capacity training. Institutions like the Nigerian Institute of Medical Research (NIMR) and major universities with public health programs can help by creating machine-learning models for resistance prediction, conducting antibiotic use surveys, and training healthcare professionals in digital health technologies [8]. Academic research can also help inform evidence-based policies, ensuring that AMR interventions are customised to Nigeria's healthcare setting.

Integrating digital surveillance into Nigeria's healthcare system involves a cross-sectoral approach that includes public-private partnerships, pharmacy networks, community health reporting, real-time policymaker dashboards, and academic research. By seizing these opportunities, Nigeria may establish a resilient surveillance infrastructure that improves antibiotic stewardship, lowers resistance, and improves public health security [37].

Challenges and Ethical Considerations. While digital surveillance appears to be a potential strategy for combating antimicrobial resistance (AMR) in Nigeria, its implementation poses substantial hurdles and ethical considerations. Addressing these concerns is critical for the long-term success and adoption of digital health solutions [1].

Data Privacy and Patient Consent. One of the most critical ethical issues in digital monitoring is data privacy. Collecting and keeping patient health details, such as antibiotic prescriptions and resistance patterns, raises concerns about privacy and illegal access [38]. Many Nigerians are ignorant of how their medical data is utilised, making informed consent a vital consideration. Without strong data privacy regulations and strict enforcement, malicious actors may misuse sensitive health information or cause it to fall into the wrong hands. To overcome this, Nigeria must establish clear regulatory frameworks that respect patient rights while allowing health data to be utilised for antimicrobial resistance surveillance [38].

Infrastructure Limitations. Poor healthcare and technology infrastructure are significant obstacles to establishing digital surveillance systems. Many public hospitals still use paper records, and the lack of standardised electronic health systems leads to fragmented data collection [30]. Furthermore, fluctuating power supply and unreliable internet connectivity – particularly in rural areas – limit the deployment of cloud-based AMR tracking technologies. Without a significant investment in health IT infrastructure, digital surveillance activities may be futile [32].

Sustainability of Donor-Funded Systems. International organisations and donors sponsor many of Nigeria's digital health programs. While these programs make essential initial expenditures, they sometimes lack long-term sustainability plans [39]. When donor financing expires, initiatives fail due to insufficient local funding and technical support. To maintain continuity, Nigeria must emphasise government ownership of digital health programs, commit domestic resources, and form public-private partnerships to keep AMR surveillance systems operational [28].

Digital Divide: Urban vs. Rural Disparities. Nigeria has a vast digital divide between its urban and rural areas. While major cities have easier access to electronic health records and mobile health platforms, many rural areas lack basic digital infrastructure. Low digital literacy among rural healthcare professionals exacerbates the divide. Focused investments in rural digital health infrastructure, mobile-based solutions designed for low-resource settings, and capacity-building programs to train healthcare personnel in digital surveillance are required to close the digital health gap [40].

CONCLUSIONS

Antimicrobial resistance (AMR) in Nigeria is increasing due to improper prescription, administration, overuse of antibiotics, inadequate surveillance, and regulatory deficiencies. Digital surveillance technologies offer a transformative solution by enabling real-time monitoring of antibiotic usage and resistance patterns. To ensure successful implementation, governments and health organisations must address data privacy, infrastructural limitations, donor dependency, and rural-urban disparities. A digital transformation is urgently needed to enhance antimicrobial resistance (AMR) surveillance and ensure effective antibiotic stewardship;

Policymakers must implement initiatives at the policy level to achieve this. The Nigerian government must invest in digital health infrastructure, especially in rural regions, and combine electronic health records (EHRs), pharmacy networks, and mobile health reporting tools into a centralised AMR tracking system. Strengthening data protection regulations and encouraging public participation through awareness campaigns will be crucial in addressing ethical concerns and restoring public trust.

Effective multi-sectoral coordination remains a crucial intervention for the sustainability of digital surveillance initiatives. The government, commercial sector, research institutions, and healthcare providers must collaborate to establish enduring funding models, enforce antibiotic regulations, and promote antimicrobial resistance (AMR) surveillance innovation. Nigeria can effectively safeguard public health and mitigate antibiotic resistance by leveraging digital technology and fostering robust partnerships.

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