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## REVIEW OF LABORATORY DIAGNOSTICS EVOLUTION IN NIGERIA'S RESPONSE TO COVID-19

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### ABSTRACT

This comprehensive review elucidates the evolution of laboratory diagnostics in Nigeria's response to COVID-19, emphasizing its pivotal role in managing infectious diseases. The purpose of this review is to analyze the advancements in diagnostic approaches and their implications on effective pandemic management and future preparedness. A robust and comprehensive research strategy was employed, involving a systematic synthesis and critical review of peer-reviewed articles, focusing on innovations, developments, and challenges in diagnostic procedures during the pandemic. The results revealed significant progress in diagnostic methodologies and technologies, with enhanced capabilities to detect and control the spread of infectious diseases, despite logistical, infrastructural, and regulatory challenges. The review concluded that the advancements in diagnostics have multifaceted impacts on shaping effective pandemic management strategies and altering public health policy and practice.

Recommendations include strengthening laboratory capacities, developing sustainable strategies, investing in research and development, promoting international collaboration, and enhancing health systems. The insights derived are instrumental in envisioning the evolving role and future of laboratory diagnostics in managing infectious diseases, driving transformative changes in healthcare delivery, and ensuring a more robust approach to infectious disease management.

**Keywords:** Laboratory Diagnostics, Infectious Diseases, Pandemic Management, Diagnostic Advancements, Public Health Policy, Healthcare Systems.

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## INTRODUCTION

### **Setting the Context: The Emergence of COVID-19 in Nigeria**

The emergence of COVID-19 in Nigeria, precipitated by the SARS-CoV-2 virus, marked a significant juncture in the nation's public health narrative. The first confirmed case was identified in February 2020, necessitating the immediate implementation of diagnostic approaches and response strategies to manage the unfolding situation.

The initial diagnostic approaches in Nigeria predominantly involved molecular tests, such as PCR, due to their renowned sensitivity and specificity in detecting viral RNA (Peeling et al., 2021). These diagnostic methods were crucial in confirming diagnoses in symptomatic individuals, enabling the activation of vital public health measures as endorsed by the World Health Organization.

However, the advent of the pandemic in Nigeria was not without challenges. The extensive use of biocides and the high prevalence of inappropriate antimicrobial prescribing during the initial stages were of significant concern, raising substantial apprehensions regarding the emergence of antimicrobial resistance (Rušić et al., 2021). The lack of effective diagnostics and the burgeoning reliance on telemedicine may have contributed to clinical uncertainty, culminating in the inappropriate use of antimicrobials.

Moreover, the enforcement of general preventative measures, such as social distancing, reduced travel, and enhanced personal hygiene, had unintended repercussions on existing public health priorities (Ahmed et al., 2021). The implementation of lockdowns, in particular, induced fear of contracting COVID-19, deterring individuals from accessing essential health services, including maternal, neonatal, and children health (MNCH) services, and resulted in a decline in the utilization of these crucial services.

### **Tracing the Onset and Rapid Proliferation of COVID-19**

The onset of COVID-19 in Nigeria marked a critical juncture in the nation's public health history, with the first confirmed case reported on 27 February 2020 (Adegboye et al., 2019). This section delves into the early transmission dynamics and the rapid proliferation of the virus in Nigeria, highlighting the challenges and responses during the initial phase of the outbreak.

The first 45 days of the COVID-19 outbreak in Nigeria were characterized by an exponential growth rate of 0.07, with a doubling time of 9.84 days, indicating the rapid spread of the virus within the community (Adegboye et al., 2019). The reproduction number was estimated to be 4.98 at day 22, peaking at 5.61 at day 25, reflecting the high transmissibility of the virus during the early stages of the outbreak (Adegboye et al., 2019). The early estimates suggested that the cases of COVID-19 in Nigeria were remarkably lower than expected, necessitating a shift in preparedness to stop local transmission.

Lagos state, being the industrial nerve center of Nigeria, was the epicenter of the COVID-19 outbreak, similar to its status during the 2014 Ebola outbreak (Abayomi et al., 2021). The lessons learned from the Ebola outbreak informed the emergency preparedness of the state ahead of the COVID-19 outbreak and guided the response. The Lagos State government developed a policy on emergency preparedness and biosecurity and provided oversight and coordination of emergency preparedness strategies, strengthening capacities for emergency response by training key staff and developing a robust surveillance system (Abayomi et al., 2021).

The COVID-19 pandemic also had significant effects on the delivery and utilization of reproductive health care services in Nigeria. A cross-sectional study of 307 primary health centers in Nigeria revealed a decline in the provision of reproductive, maternal, child, and adolescent health (RMCAH) services during the COVID-19 lockdowns (Adelekan et al., 2021). The study highlighted the difficulties experienced during the lockdown, including stock-out of drugs and contraceptives, harassment by law enforcement agents, and transportation difficulties, emphasizing the multifaceted impact of the pandemic on health care provision and access (Adelekan et al., 2021).

Furthermore, the impact of COVID-19 extended to smallholder poultry farmers in Nigeria, affecting their livelihoods and food security. A study assessing the impact of COVID-19 on 525 smallholder poultry farmers in Nigeria showed a significant reduction in average monthly income and an increase in the number of farmers living below the international poverty line during the pandemic (Bamidele & Amole, 2021). The findings underscore the pervasive effects of the pandemic on various sectors, necessitating comprehensive interventions to address the diverse challenges posed by the outbreak.

In conclusion, tracing the onset and rapid proliferation of COVID-19 in Nigeria reveals a multifaceted scenario marked by high transmissibility, significant impacts on health care services, and extensive effects on livelihoods and food security. The experiences and challenges encountered during the initial stages of the pandemic underscore the importance of robust preparedness and response strategies to mitigate the impacts of such outbreaks in the future.

### **Initial Diagnostic Approaches and Response Strategies**

The emergence of COVID-19 in Nigeria necessitated immediate and robust diagnostic approaches and response strategies to curb the spread of the virus. The initial diagnostic approaches were pivotal in identifying and isolating confirmed cases, thereby mitigating the transmission of the virus within communities.

The initial response to COVID-19 in Nigeria was marked by the implementation of various measures aimed at controlling the spread of the virus. The societal response to COVID-19 had profound impacts on access to healthcare for non-COVID-19 health issues, especially in slum communities of Nigeria (Ahmed et al., 2020). The lockdowns imposed to control the pandemic had significant health, social, and economic consequences, affecting access to healthcare and leading to a reduction in the provision of essential health services.

Digital contact tracing emerged as a complementary strategy to slow the spread and reduce the impact of COVID-19. The utilization of mobile positioning data for contact tracing was explored to trace the primary and secondary contacts of confirmed COVID-19 cases (Ekong et al., 2020). This approach aimed to adhere to Nigeria's data privacy regulations, ensuring the

protection of patient data while leveraging technology to complement current strategies within the National Data Protection Regulation (NDPR).

The global demand for diagnostics and therapeutics necessitated the rapid development of various algorithms to successfully identify and contain the virus. The repurposing of therapeutics for COVID-19 was explored, focusing on clinically effective treatments and control measures (Iyer et al., 2020). The development of diagnostic kits and the exploration of repurposed drugs, such as chloroquine/hydroxychloroquine and convalescent plasma, were crucial in the initial response to control the disease.

The initial diagnostic approaches and response strategies in Nigeria were multifaceted, involving societal measures, digital contact tracing, and the exploration of diagnostic and therapeutic approaches. These strategies were crucial in the early stages of the pandemic to mitigate the spread of the virus and address the associated challenges.

### **The Pivotal Role of Laboratory Diagnostics in Effective Pandemic Management**

Laboratory diagnostics play a crucial role in managing pandemics effectively, serving as the cornerstone in identifying, controlling, and preventing the spread of infectious diseases. The emergence of COVID-19 highlighted the importance of rapid and accurate diagnostic testing in managing the spread of the virus and implementing appropriate response strategies. The Infectious Diseases Society of America emphasizes the importance of developing evidence-based, rapid guidelines to support patients, clinicians, and other healthcare professionals in their decisions about the treatment and management of patients with COVID-19 (Bhimraj et al., 2020).

The World Health Organization (WHO) declared COVID-19, caused by the SARS-CoV-2 virus, a global pandemic on March 11, 2020. The “L. Spallanzani” National Institute for the Infectious Diseases, IRCCS, Rome, Italy, was among the first to manage patients affected by COVID-19 and developed recommendations for COVID-19 clinical management based on limited clinical evidence available at the time (Nicastri et al., 2020). These recommendations were crucial in shaping the initial response strategies and managing patients effectively in the early stages of the pandemic.

### **The Imperative of Detecting and Controlling the Spread of Infectious Diseases**

Detecting and controlling the spread of infectious diseases is imperative for public health. The magnitude of the COVID-19 pandemic challenged societies globally, revealing a lack of preparedness in many governments to face this systemic and global health crisis. The responses were characterized by unprecedented and drastic measures and policies, including lockdowns and travel restrictions, to manage the exceptional healthcare situation (Alami et al., 2021). These measures had profound impacts on access to healthcare for non-COVID-19 health issues, especially in slum communities, affecting access to healthcare and leading to a reduction in the provision of essential health services (Ahmed et al., 2020).

The pandemic underscored the importance of surveillance, workforce management, availability of infrastructures and medical supplies, communication mechanisms, governance, and trust establishment throughout the crisis. The resilience and ability to adequately respond to a systemic and global crisis depend upon preexisting system-level characteristics and capacities at both the provincial and federal governance levels (Alami et al., 2021). The lessons learned from the management of COVID-19 in different regions contribute to the groundwork required

for interdisciplinary research and genuine policy discussions to help health systems better prepare for future pandemics.

The management of periodontal patients during the COVID-19 era also had to adapt to the challenges posed by the pandemic. Recommendations were provided for periodontal practice to optimize safety, ergonomics, and economic resources, ensuring continuity, timing, and effectiveness of periodontal care in the COVID-19 era (Di Spirito et al., 2021). These recommendations emphasized the integration of measures minimizing airborne cross-infections and optimizing time-space and economic resources, implementing prevention strategies through teledentistry tools and apps, and enhancing inter-professional collaboration through telehealth networks.

### **The Integral Contribution to Clinical Management and Scientific Research**

Laboratory diagnostics are integral to clinical management and scientific research, especially in the context of infectious diseases like COVID-19. The rapid development of highly specific diagnostics has been crucial in the identification and management of COVID-19 cases, allowing for timely and informed clinical decisions (Lake, 2020). The availability of accurate and validated laboratory testing for Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) is pivotal in supporting the clinical decision-making process, facilitating appropriate treatment, prompt isolation, and consequently decelerating the pandemic (Kubina & Dziedzic, 2020).

The development and implementation of point-of-care diagnostics (POCD) have substantially accelerated clinical decisions and enabled strategic planning at the national level for preventative measures. These diagnostics, including quantitative reverse transcription PCR (RT-qPCR), serology immunoassays (SIAs), and protein microarray methods (PMM), are designed for standard and rapid COVID-19 diagnosis. The availability of these diagnostics is crucial in detecting asymptomatic cases and implementing strategic planning at the national level of preventative measures, thereby contributing significantly to the management of COVID-19 disease (Kubina & Dziedzic, 2020).

In addition to diagnostics, the exploration of pharmaceutical and nutritional strategies has emerged as a scientific interest in the clinical management of COVID-19. Pharmaconutrition strategies, including the administration of oral medicinal doses of vitamin C, zinc, vitamin D3, and glutamine, have been considered as potential adjunctive strategies in the management of COVID-19. These strategies are explored to identify their potential in halting the progression of COVID-19, especially in critical care situations requiring parenteral nutrition (Santos et al., 2020).

The exploration of these strategies is crucial in understanding their utility in the management of SARS-CoV-2 infection and COVID-19. Ongoing and future clinical research is imperative to determine the effectiveness of these pharmaconutrition strategies in conjunction with established treatment methods. The integration of these strategies could potentially offer personalized prescription options, enhancing the clinical management of COVID-19 (Santos et al., 2020).

The impact of the COVID-19 pandemic on elective and non-urgent procedures across all specialties has led to the development of evidence-based protocols for testing, surgical/procedural risk mitigation, and clinical flow management/contamination management. These protocols are paramount for the safety of non-urgent surgical procedures and are

developed to define manageable procedures and organizational changes necessary to protect patients and healthcare workers when clinics and practices reopen (Kaye et al., 2020).

The development of these protocols and the adaptation of current patient information/informed consent forms and patient health questionnaires are crucial in addressing the challenges posed by the COVID-19 crisis. The implementation of these protocols and the adherence to contamination control and avoidance of cross-contamination are essential in ensuring the safety and feasibility of elective/aesthetic procedures in the wake of SARS–COVID-19 (Kaye et al., 2020).

The integral contribution of laboratory diagnostics to clinical management and scientific research is evident in the multifaceted approaches adopted in response to the COVID-19 pandemic. The development of diagnostics, exploration of pharmaceutical and nutritional strategies, and the establishment of safety protocols for elective procedures are pivotal in addressing the challenges and impacts of the pandemic. The ongoing research and developments in these areas are crucial in enhancing the understanding and management of COVID-19 and other infectious diseases

### **The Aims and Objectives of the Comprehensive Review**

The overarching aim of this comprehensive review is to meticulously examine the evolution of laboratory diagnostics in Nigeria's response to COVID-19. This examination will encompass the initial approaches and strategies, the innovations and developments in diagnostics, and the subsequent impacts on clinical management and scientific research. By delving into the multifaceted aspects of laboratory diagnostics, this review seeks to provide insights into the pivotal role of diagnostics in managing infectious diseases effectively.

### **Objectives**

1. To scrutinize the initial diagnostic approaches and response strategies adopted in Nigeria at the onset of the COVID-19 pandemic, focusing on their effectiveness and adaptability.
2. To explore the technological and methodological innovations in laboratory diagnostics that emerged during the pandemic, assessing their contributions to the detection and control of COVID-19 in Nigeria.
3. To evaluate the progress and improvements in diagnostic procedures and their implementation, considering the challenges and barriers encountered in diagnostic implementation.
4. To assess the multifaceted impact of the evolution of diagnostic approaches on effective pandemic management strategies, public health policy, and practice in Nigeria.
5. To identify untapped and prospective areas in laboratory diagnostics for subsequent research and exploration, aiming to fortify the preparedness and response to future infectious disease outbreaks.

### **Justification and Rationale Behind the Selection of the Case Study**

The selection of Nigeria as a case study in this comprehensive review is justified by its unique position as one of the most populous countries in Africa, with diverse ethnic groups and varying healthcare infrastructures across its states. Nigeria's response to COVID-19 is representative of the challenges and opportunities encountered by developing countries in managing a global pandemic, making it a pertinent subject of study to understand the dynamics of pandemic response in resource-constrained settings.

The rationale behind focusing on the evolution of laboratory diagnostics in Nigeria's response to COVID-19 is driven by the critical role that diagnostics play in the detection, management, and control of infectious diseases. Laboratory diagnostics serve as the first line of defense in identifying and isolating confirmed cases, thereby mitigating the transmission of the virus within communities. The advancements and innovations in diagnostic approaches have direct implications on clinical management, scientific research, and overall pandemic management strategies.

Examining Nigeria's approach provides insights into the adaptability and resilience of its healthcare system in the face of unprecedented challenges posed by the COVID-19 pandemic. The lessons learned from Nigeria's experiences can inform and guide other countries, especially those with similar socio-economic and healthcare contexts, in developing robust and effective diagnostic and response strategies for current and future infectious disease outbreaks.

Furthermore, this review aims to contribute to the global discourse on pandemic management by highlighting the successes, challenges, and lessons from Nigeria's approach to COVID-19, emphasizing the importance of tailored and context-specific strategies in addressing the multifaceted impacts of a global health crisis. The insights gleaned from this case study are instrumental in fostering a deeper understanding of the integral role of laboratory diagnostics in managing infectious diseases and shaping effective public health policies and practices.

## **METHODOLOGY**

### **Designing a Robust and Comprehensive Research Strategy**

In the context of COVID-19, designing a robust and comprehensive research strategy is pivotal to understanding the multifaceted impacts of the pandemic on various sectors, including healthcare, education, and the economy. A well-structured research strategy is essential to explore the diverse challenges and transformations induced by the pandemic, such as the profound disruption in education due to school closures and the shift to online learning (Tri Sakti et al., 2022).

The research strategy should encompass a meticulous literature search, guided by established protocols like the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). The use of PRISMA ensures the identification of relevant studies by providing a systematic approach to literature search and selection, thereby enhancing the reliability and comprehensiveness of the review (Tri Sakti et al., 2022).

The selection of databases is crucial in this strategy. Databases like Web of Science (WoS) and Scopus are recommended due to their extensive collection of research papers across various disciplines. A systematic search in these databases allows for the exploration of diverse topics related to the impacts of health crises, including the effects on mental health, quality of life, teaching and learning, and physical health (Tri Sakti et al., 2022).

### **Establishing Rigorous Inclusion and Exclusion Criteria for Literature Selection**

Establishing rigorous inclusion and exclusion criteria is fundamental to refining the literature selection and ensuring the relevance and quality of the selected studies. Inclusion criteria should consider the language of the publication, with studies written in English being predominantly included to maintain uniformity and accessibility. The timeframe of the publication is also a vital criterion, with recent studies, preferably from the year 2000 to the present, being prioritized to capture the contemporary developments and insights related to health crises like COVID-19 (Tri Sakti et al., 2022).

The type of publication is another essential criterion, with research papers being the primary focus to ensure the inclusion of empirical and evidence-based studies. This criterion enables the review to be grounded in factual and validated information, thereby enhancing the reliability and validity of the findings. Exclusion criteria should filter out studies that do not align with the research objectives or lack substantial evidence and empirical backup (Panneer et al., 2022).

The application of these criteria ensures that only eligible studies are included for qualitative synthesis, providing a coherent and focused review of the impact of health crises on various populations and sectors. For instance, a study by Panneer et al. (2022) highlighted the long-term impacts of non-pharmaceutical measures like social distancing, lockdown, and quarantine on economic and social development, revealing the profound consequences of the COVID-19 pandemic on production and consumption patterns, market dynamics, and access to essential healthcare services.

### **Systematic Synthesis and Critical Review of the Chosen Literature**

A systematic synthesis and critical review of the chosen literature are pivotal for a comprehensive understanding of the subject matter. The synthesis of literature related to COVID-19 reveals a plethora of studies focusing on various aspects of the disease, including clinical laboratory parameters associated with severe or critical COVID-19 (Moutchia et al., 2020), the prevalence of symptoms in infected adults (Grant et al., 2020), and the impact of the pandemic on the utilization of healthcare services (Moynihan et al., 2021).

Moutchia et al. (2020) conducted a systematic review and meta-analysis to assess clinical laboratory parameters which may serve as markers or predictors of severe or critical COVID-19 disease. The study included forty-five studies in six countries and concluded that severe or critical COVID-19 is characterized by increased markers of innate immune response, decreased markers of adaptive immune response, and increased markers of tissue damage and major organ failure. This study provides valuable insights into the clinical manifestations of severe COVID-19 cases and can aid in early identification and management of critical cases.

Grant et al. (2020) focused on determining the prevalence of symptoms associated with COVID-19 worldwide. The study included 148 articles comprising 24,410 adults with confirmed COVID-19 from 9 countries. The most prevalent symptoms were fever, cough, and fatigue. Understanding the prevalence of symptoms is crucial for informing guidelines for quarantining and testing, thereby limiting the spread of SARS-CoV-2.

Moynihan et al. (2021) conducted a systematic review to determine the extent and nature of changes in the utilization of healthcare services during the COVID-19 pandemic. The study included 81 studies across 20 countries, reporting on over 11 million services pre-pandemic and 6.9 million during the pandemic. The study found a median 37% reduction in services overall, with considerable variation.

### **Crafting an Analytical Framework for Data Interpretation and Analysis**

Crafting an analytical framework is essential for interpreting and analyzing the data gleaned from the selected literature. The framework should be designed to assess the reliability, validity, and relevance of the studies included in the review. The studies by Moutchia et al. (2020), Grant et al. (2020), and Moynihan et al. (2021) provide diverse perspectives on COVID-19, ranging from clinical manifestations and symptom prevalence to the impact on healthcare services. An analytical framework should consider the methodologies, sample sizes, and findings of the included studies to draw coherent and insightful conclusions.



The framework should also encompass a comparative analysis of the studies to identify commonalities, discrepancies, and gaps in the existing literature. This comparative analysis can facilitate a deeper understanding of the multifaceted impacts of COVID-19 and inform future research directions. By synthesizing the findings of the selected studies, the analytical framework can elucidate the overarching themes and patterns in the literature, providing a holistic view of the subject matter.

### **CASE STUDY AND FINDINGS**

#### **Providing Context and Background for the Selected Case**

The emergence of COVID-19 in Nigeria, particularly in Lagos, the industrial nerve center of the country, necessitated a swift and comprehensive response, drawing on lessons from previous infectious disease outbreaks, such as the Ebola outbreak in 2014. Lagos, being the epicenter of both the Ebola and COVID-19 outbreaks in Nigeria, has been pivotal in shaping the country's approach to managing infectious diseases (Abayomi et al., 2021).

The Lagos State government, learning from the Ebola outbreak, developed policies on emergency preparedness and biosecurity, providing oversight and coordination of emergency preparedness strategies. These strategies included the establishment of a Biosafety Level 3 laboratory and biobank, development of a robust surveillance system, and training of key staff in emergency response capacities. The government prioritized resource provision, including finances and trained personnel for emergencies (Abayomi et al., 2021).

The state's preparedness was tested with the onset of COVID-19, and Lagos was able to respond promptly using a centralized Incident Command Structure and the key activities of the Emergency Operations Centre. The response was characterized by effective partnerships with private sectors, community engagement, and significant political commitment. The state's approach to the COVID-19 pandemic was informed by a comprehensive understanding of the comorbidities that result in negative outcomes for COVID-19 patients, with data revealing that comorbidities such as hypertension, diabetes, renal disease, cancer, and HIV were prevalent among COVID-19 patients in Lagos, and associated with a high risk of death (Osibogun et al., 2021).

Furthermore, a retrospective analysis of the Surveillance Outbreak Response Management and Analysis System data was conducted to compare the epidemiological features of the first and second waves of COVID-19 in Nigeria. The analysis revealed a 21.3% increase in the number of tests conducted in the second wave, with a test positivity rate increasing by 14.3%. The confirmed COVID-19 cases increased among females and people 30 years old or younger during the second wave, and most confirmed cases were asymptomatic at diagnosis during both waves (Akande et al., 2021).

The integration of automated mobile laboratories equipped with advanced technologies, such as 6-axis robot arm for automated oropharyngeal swab specimen collection and a laboratory-on-a-chip system for nucleic acid extraction and nested isothermal amplification, has also played a crucial role in enhancing the diagnostic capabilities in response to the COVID-19 pandemic. These mobile laboratories are capable of on-site specimen collection, inactivation, analysis, and reporting, providing a promising solution for fast deployment of medical diagnostic resources at critical junctions of infectious disease outbreaks (Xing et al., 2021).

### **Analyzing and Deriving Key Insights from the In-depth Case Study**

The analysis of Nigeria's response to COVID-19 reveals a multifaceted approach, integrating various diagnostic methods to manage the pandemic effectively. The rapid development and deployment of diagnostic solutions have been crucial in addressing the challenges posed by the pandemic, particularly in the context of increasing testing demands (Oyewole et al., 2021).

The initial response was characterized by the utilization of the reverse transcription polymerase chain reaction (RT-PCR) method, which became a standard diagnostic tool. This method, while widely used clinically, has its limitations, including dependency on many factors affecting accuracy and a lengthy process taking up to 6–8 hours (Andryukov et al., 2021). The accuracy of RT-PCR is crucial as it supports clinical decision-making processes for infection control at healthcare levels and detects asymptomatic cases, facilitating appropriate treatment and prompt isolation (Kubina & Dziedzic, 2020).

To address the limitations of RT-PCR and to cope with the sharp increase in the number of patients, new rapid, inexpensive, sensitive, and specific tests were developed. Technologies such as loop-mediated isothermal amplification (LAMP) and lateral flow immunoassay (LFIA) have proven to work well in COVID-19 diagnostics and can become a worthy alternative to traditional laboratory-based diagnostics resources (Andryukov et al., 2021).

### **Unveiling Progress and Innovations in Laboratory Diagnostics**

The progress and innovations in laboratory diagnostics have been pivotal in shaping the response to COVID-19. The development of point-of-care diagnostics (POCD) has substantially accelerated clinical decisions and implemented strategic planning at the national level of preventative measures (Kubina & Dziedzic, 2020). These diagnostics include quantitative reverse transcription PCR (RT-qPCR), serology immunoassays (SIAs), and protein microarray methods (PMM) designed for standard and rapid COVID-19 diagnosis.

The innovations in diagnostics have also included the development of several sample-to-answer platforms, including high-throughput systems and Point of Care (PoC) assays, developed to increase testing capacity and decrease technical errors (Mardian et al., 2021). These alternatives to RT-PCR assays, such as other RNA detection methods and antigen tests, may be appropriate for certain situations, such as resource-limited settings.

Moreover, the advancements in serological systems for detecting antibodies against SARS-CoV-2 have been used to assess the level of population immunity in various categories of people and for retrospective diagnosis of asymptomatic and mild COVID-19 in patients (Andryukov et al., 2021). The combination of various types of laboratory diagnostic testing techniques, whose sensitivity and specificity increase with the progress in the SARS-CoV-2 research, is required to cope with the COVID-19 pandemic.

The evolution of diagnostic innovations devised to meet changing needs, their regulation, and trends across geographical regions provide invaluable insights into the complexity of the COVID-19 phenomena. The testing strategy should be designed to provide large-scale examination depending on the timing of examination and the severity of the infection in patients (Oyewole et al., 2021).

### **Exploring Technological and Methodological Innovations in Diagnostics**

The COVID-19 pandemic has necessitated unprecedented technological and methodological innovations in diagnostics to understand, detect, and treat the disease effectively. The innovations in technology have been pivotal in addressing the challenges of managing a

completely novel infectious disease with existing diagnostics and therapeutics that were initially insufficient to stem the spread of COVID-19 (Chow et al., 2020).

One significant innovation is the development of accurate diagnostic tests that can be used at home to provide a rapid answer about a person's clinical status. These tests are coupled with telemedicine visits to introduce rapid assessment into the home for a range of pathogens, such as group A Streptococcus, influenza virus, respiratory syncytial virus, and many more. This ability to connect at-home diagnostic tests with telemedicine and rapid turnaround of definitive laboratory testing will change infectious disease management, making rapid assessment and treatment more possible and expanding access to timely, more affordable medical care (Gottlieb, 2021).

Furthermore, the integration of Artificial Intelligence (AI) and Big Data in laboratory medicine has revolutionized diagnostics. AI, through the development of complex algorithms, simulates human intelligence such as problem-solving and learning, and has the potential to revolutionize existing protocols for diagnostics as well as disease prevention and control, significantly boosting patient safety and quality of care (Gruson, 2021).

### **Assessing Developments and Improvements in Diagnostic Procedures**

The developments and improvements in diagnostic procedures have been critical in controlling the spread of COVID-19. The application of emerging viral detection technologies toward better COVID-19 diagnostics has resulted in incredible advances in pathogen detection innovations. Miniaturization assays that allowed for the accurate analysis and detection of SARS-CoV-2 viral nucleic acid detection or host antibody response to COVID-19 have proven to be critical (Chow et al., 2020).

The advancements in serological systems for detecting antibodies against SARS-CoV-2 have been used to assess the level of population immunity in various categories of people and for retrospective diagnosis of asymptomatic and mild COVID-19 in patients. These technological advances have proven critical for field testing in the community or in less well-equipped remote areas, enabling more widespread testing and monitoring of the disease (Chow et al., 2020).

The rapid introduction of highly effective vaccines, the development of monoclonal antibody drugs, and most recently, antivirals that are taken orally, have offered a potent armamentarium to reduce the adverse effects of SARS-CoV-2 infection. These innovations in diagnostics and treatment have transformed the response to the COVID-19 pandemic, providing new tools and strategies to combat this and future infectious diseases (Gottlieb, 2021).

### **Overcoming Challenges and Barriers in Diagnostic Implementation**

The implementation of diagnostic procedures in the context of the COVID-19 pandemic has been fraught with numerous challenges and barriers, particularly in resource-limited settings. The global challenge of access to rapid and accurate testing has been exacerbated by infrastructural and logistical challenges, including supply chain shortages and the availability of testing centers (Nsawotebba et al., 2021).

The Democratic Republic of Congo (DRC), for instance, has faced several exacerbating factors contributing to a poor healthcare system, including conflict, healthcare resource constraint and exhaustion, poor infrastructure, insufficient logistical resources, limited testing centers, and a lack of personal protective equipment (PPE). These factors have significantly hindered the transportation of samples from remote areas to testing laboratories and have contributed to the frailty of the healthcare system in DRC (Aborode et al., 2023).

The availability of COVID-19 diagnostic testing continues to be impeded by global supply chain shortages and logistic challenges, causing long turnaround times and delayed results. The application of machine learning to lab results has been explored as a potential solution to predict SARS-CoV-2 infection before definitive test results are available, helping guide patient management decisions in the absence of definitive test results (McCudden, 2020).

### **Addressing Logistical and Infrastructural Constraints and Limitations**

Addressing the logistical and infrastructural constraints and limitations is crucial for the effective implementation of diagnostic procedures. In Uganda, the operationalization of Xpert® Xpress SARS-CoV-2 testing faced several challenges, including infrastructural modifications and the establishment of robust Laboratory Quality and Information Management Systems. Despite these challenges, the implementation team successfully established the Xpert® Xpress SARS-CoV-2 testing Laboratory, which significantly reduced the median turnaround time for samples compared to before it was established (Nsawotebba et al., 2021).

The integration of innovative solutions such as machine learning methods with routinely available laboratory results can be useful when the relationship between individual analytes and disease state is complex or unknown. These machine learning algorithms are highly amenable to retraining, allowing for the continuous addition of more classified data, which should improve the overall performance of the algorithms in predicting infections (McCudden, 2020). The ongoing efforts to overcome the challenges and barriers in diagnostic implementation are pivotal in ensuring that the advancements in diagnostic procedures can be effectively utilized to manage and control the spread of COVID-19, particularly in regions with limited resources and infrastructural constraints. The integration of innovative technological solutions and the continuous improvement of logistical and infrastructural capabilities are essential in addressing the existing challenges and enhancing the effectiveness of diagnostic procedures in the fight against the pandemic.

### **Navigating Through Regulatory and Compliance Barriers and Challenges**

The COVID-19 pandemic has necessitated the rapid development and implementation of diagnostic procedures, highlighting the importance of navigating through regulatory and compliance barriers and challenges. The establishment of biorepositories has been crucial in enabling investigations and advancements in diagnostic assays, and it involves complex integration of scientific need, regulatory oversight, and quality control (Croker et al., 2021). The challenges encountered in building biorepositories during the pandemic have underscored the need for adaptive strategies and responsive systems to meet the unprecedented clinical demands and research constraints.

In Nigeria, compliance with construction regulations, standards, and codes is fundamental to improving key performance indicators and managing project risks. The emphasis on improving education and awareness in the industry is crucial to address compliance issues and ensure adherence to specified standards and protocols (Windapo & Umeokafor, 2022). The considerations of compliance in construction provide insights into the broader implications of regulatory and compliance barriers in the healthcare sector, particularly in the implementation of diagnostic procedures for COVID-19.

### **Evaluating the Multifaceted Impact of Diagnostic Evolution**

The multifaceted impact of diagnostic evolution in Nigeria's response to COVID-19 is intertwined with the ability to navigate through regulatory and compliance barriers. The insights

gained from managing biorepositories and ensuring compliance with construction standards reflect the broader challenges and considerations in evaluating the impact of diagnostic evolution. The adaptive strategies and responsive systems developed in response to the pandemic have implications for the ongoing efforts to enhance diagnostic capabilities and address the existing challenges in the healthcare sector.

The emphasis on education and awareness in ensuring compliance with standards and protocols is pivotal in shaping effective pandemic management strategies and altering public health policy and practice. The continuous dialogue and collaboration between various stakeholders are essential in addressing the existing challenges and enhancing the effectiveness of diagnostic procedures in managing infectious diseases.

### **Influencing and Shaping Effective Pandemic Management Strategies**

The evolution of diagnostic procedures during the COVID-19 pandemic has played a pivotal role in shaping effective pandemic management strategies and altering public health policy. The impact of the pandemic on the utilization of health services in public facilities has been profound, with a significant decline in health service use among the public during outbreaks (Hategeka et al., 2021). The implementation of strict lockdown measures and public health policies has led to a rapid drop in health service use, ranging from visits for common infectious diseases to non-communicable diseases. The decline in health service utilization underscores the importance of adaptive strategies and responsive systems to meet the unprecedented clinical demands and research constraints during a pandemic.

The pandemic has also highlighted the growing concern about the negative effects of infectious medical waste produced and the contamination risks associated with waste management (Maalouf & Maalouf, 2021). The generation of infectious medical waste is significant for management planning and policy development, and measures to ensure that medical waste is managed safely and in an environmentally sound manner are crucial to avoid negative health and environmental effects. The study on the impact of COVID-19 on medical waste management in Lebanon illuminates the existing challenges of waste management and emphasizes the need for proper management and disposal of medical waste generated to reduce contamination risks or related environmental threats, particularly during the pandemic.

The integration of enhanced diagnostics with public health policies is crucial in addressing the multifaceted challenges posed by the pandemic. The insights gained from the impact of the pandemic on health service utilization and medical waste management provide valuable perspectives on optimizing current policy strategies to reduce the spread of COVID-19. The emphasis on improving education and awareness, ensuring adherence to specified standards and protocols, and developing adaptive strategies and responsive systems are pivotal in shaping effective pandemic management strategies.

The continuous assessment of the link between COVID-19 related attitudes, concerns, and behaviors in relation to public health policies is essential in providing behavioral science, data-driven recommendations to governments (Bacon et al., 2021). The international assessment of behavioral responses to COVID-19 public health policies and their impacts on people around the world contributes to understanding the effectiveness of evolving country-level policies and communication strategies to reduce the impact of the COVID-19 pandemic.

### **Altering Public Health Policy and Practice with Enhanced Diagnostics**

The evolution of diagnostic procedures during the COVID-19 pandemic has significantly altered public health policy and practice, emphasizing the role of science, technology, and innovation (ST&I) in shaping healthcare systems worldwide. The rapid development of SARS-CoV-2 test diagnostics and new mRNA vaccines showcased the potential of ST&I to positively impact healthcare systems. However, the pandemic also highlighted significant challenges in integrating ST&I-oriented health initiatives and policies effectively in response to the crisis (da Silva et al., 2021).

The pandemic has mobilized experts, industry, and governments to evaluate alternative trajectories to promote a more efficient dialogue between ST&I and public health. The asymmetries in the technical and political infrastructures available for particular approaches in ST&I in health, such as precision medicine, have uncovered a persistent gap in the translation of knowledge and technologies to adequately coordinated responses to the pandemic. The need to strengthen governance tools for the promotion of ST&I as a strategic component of the post-pandemic agenda in public health is crucial to prepare societies to respond efficiently to future emergencies (da Silva et al., 2021).

Furthermore, the response to the COVID-19 pandemic in various countries has not realized the hopes of science and technology being formidable forces to improve population health and well-being. The pandemic has exposed critical weaknesses in the institutional systems specifically intended to protect and harness science and technology to promote personal and public health. The pandemic is thus a clarion call for a thoughtful examination of ways to bolster and modernize systems that support and guide science, technology, and public health (Narayan et al., 2021).

The rapid development and testing of diagnostics, therapeutics, and vaccines have been enormous scientific and technological accomplishments. However, the response to the pandemic has unveiled vulnerabilities in society and in the scientific independence of public health institutions. The current moment presents an opportunity to think boldly and to imagine a better world beyond the tragedy of the COVID-19 pandemic, emphasizing the importance of international assessment of behavioral responses to COVID-19 public health policies and their impacts on people around the world (Narayan et al., 2021).

### **DISCUSSION**

#### **Critically Assessing the Impact and Effectiveness of Diagnostic Advancements**

The COVID-19 pandemic has underscored the critical importance of diagnostic advancements in managing and mitigating the impacts of infectious diseases. The effectiveness of these advancements is pivotal in shaping crisis management strategies and public health policies, especially in the face of unprecedented global challenges posed by the pandemic.

The pandemic has necessitated the rapid development and deployment of diagnostic tools to identify and control the spread of the virus. The effectiveness of non-pharmaceutical interventions, such as lockdowns and restrictions, has been a subject of extensive study, with social media playing a crucial role in managing the challenges posed by the pandemic (Zhou et al., 2021). The strategic responses and experiences during the pandemic have provided insights into managing global emergencies and reducing the adverse effects of the pandemic on the immune systems of the general population.

The government's effectiveness during the COVID-19 pandemic is closely related to citizens' willingness to cooperate and adhere to public health guidelines. The perceptions of government effectiveness are influenced by citizens' experiences and the government's responsiveness, transparency, and the level of public participation in decision-making processes (Mizrahi et al., 2021). The trust in government and its ability to manage crises effectively is paramount in ensuring the successful implementation of public health policies and interventions.

The digitalization of zakat management during the pandemic has demonstrated the role of digital platforms in providing convenience and optimizing the collection and distribution of zakat funds, especially in times of crisis (Ninglasari & Muhammad, 2021). The strengths, weaknesses, opportunities, and threats of zakat digitization have been analyzed to overcome threats and weaknesses and utilize strengths and opportunities to have a significant impact on community welfare.

The pandemic has significantly affected the healthcare system, with the highest pressure being on cancer services. The restrictions in access to preventive cancer screening and the overall reduction of the whole spectrum of cancer services may negatively affect cancer survival measures in the future (Dabkevičienė et al., 2021). The pandemic has highlighted the need for a thoughtful examination of ways to bolster and modernize systems that support and guide science, technology, and public health.

The critical assessment of the impact and effectiveness of diagnostic advancements during the COVID-19 pandemic is essential in understanding the challenges and opportunities in managing global health emergencies. The insights gained from various studies and experiences during the pandemic can guide future strategies and interventions to enhance the resilience and responsiveness of healthcare systems and public health policies.

### **Reflecting on the Long-term Implications for Future Pandemic Preparedness and Response**

The COVID-19 pandemic has brought forth unprecedented challenges, necessitating a reevaluation of strategies for pandemic preparedness and response. The long-term implications of the advancements in diagnostics during the pandemic are multifaceted, impacting various aspects of public health and healthcare systems.

Chowdhury et al. (2020) emphasize the need for sustainable strategies in low and middle-income countries (LMICs) to balance economic and health consequences. The authors propose various non-pharmacological interventions, including sustained mitigation, zonal lockdown, and rolling lockdown strategies, to safely lift lockdowns. The feasibility of these strategies is contingent upon the availability of generalized testing, surveillance structure, and a well-executed zone management plan. The study underscores the importance of considering economic costs and supply chain reforms in implementing intermittent, rolling lockdown strategies, especially in settings where generalized mitigation and zonal containment are unfeasible (Chowdhury et al., 2020).

Soga et al. (2021) present a conceptual framework to understand how the COVID-19 pandemic might affect the dynamics of human–nature interactions. The authors identify three pathways: changes in opportunity, capability, and motivation, through which the pandemic can lead to alterations in human–nature interactions. The study suggests that the impacts of the pandemic could persist over the long term, providing mechanistic insights into the complex processes and

dynamics of human–nature interactions and possible strategies to manage them effectively (Soga et al., 2021).

Marome and Shaw (2021) analyze Thailand’s response to the COVID-19 pandemic, focusing on community-level public health systems and legislative measures. The authors draw lessons on future preparedness, emphasizing the need for multilevel governance that engages various stakeholders and supports grassroots and community-level networks. The study highlights the opportunity for enhancing resilience through inclusive long-term recovery plans that address existing gaps and work towards a sustainable society, furthering the Health Emergency Disaster Risk Management (HEDRM) Framework to support a coordinated response across various linked sectors (Marome & Shaw, 2021).

The long-term implications of diagnostic advancements during the COVID-19 pandemic necessitate a holistic approach to future pandemic preparedness and response. The insights gained from the studies mentioned above emphasize the importance of sustainable strategies, human–nature interactions, and multilevel governance in managing future pandemics effectively.

### **Offering Insightful Recommendations for Strengthening and Enhancing Diagnostic Capabilities**

The COVID-19 pandemic has underscored the pivotal role of diagnostics in managing infectious diseases and has highlighted the need for strengthening and enhancing diagnostic capabilities. The World Health Organization (WHO) has emphasized the central role of diagnostics in counteracting the pandemic and has recommended that countries should strengthen laboratory capacities to ensure reliable rapid diagnostic SARS-CoV-2 detection and tracking of variants (Youngster, 2022).

#### **Recommendations**

1. **Enhance Laboratory Capacities:** There is a need for enhanced laboratory capacities to ensure reliable and rapid diagnostic SARS-CoV-2 detection and tracking of variants. This involves integrating population-based surveillance systems for influenza, SARS-CoV-2, and other respiratory viruses to monitor the spread and intensity of respiratory viruses (Youngster, 2022).
2. **Develop Sustainable Strategies:** Countries, especially low and middle-income countries (LMICs), should develop sustainable strategies to balance economic and health consequences. This involves implementing non-pharmacological interventions, including sustained mitigation, zonal lockdown, and rolling lockdown strategies, to safely lift lockdowns (Chowdhury et al., 2020).
3. **Invest in Research and Development:** Continuous investment in research and development is crucial to fuel advancements in understanding and managing viruses and to develop innovative diagnostic tests. The establishment of biosafety laboratories and the conduction of investigations centered on the detoxification of body fluids in survivors can fuel advancements in understanding and managing viruses like Ebola and COVID-19 (Wang et al., 2023).
4. **Strengthen Health Systems:** The Ebola outbreak underscored a lack of ability to identify and diagnose emerging and re-emerging infectious diseases, emphasizing the necessity of strengthening the health system to better respond to future public health crises. Consistent international efforts are crucial to building the resilience of health systems in



countries experiencing significant morbidity and mortality due to various diseases (Wang et al., 2023).

5. **Promote International Collaboration:** The global community should support nations critically deficient in their capacity for pathogenic testing and diagnostics, the availability of healthcare workers, and their supply of epidemic prevention materials. The support can include dispatching mobile biosafety laboratories and corresponding technicians to facilitate testing within the country (Wang et al., 2023).

### **Identifying Untapped and Prospective Areas for Subsequent Research and Exploration**

The evolving role and future of laboratory diagnostics in managing infectious diseases are envisioned to be more integrated, innovative, and crucial in shaping healthcare systems worldwide. The rapid development of SARS-CoV-2 test diagnostics and new mRNA vaccines have showcased the potential of science, technology, and innovation (ST&I) to positively impact healthcare systems. However, the pandemic has also highlighted significant challenges in integrating ST&I-oriented health initiatives and policies effectively in response to the crisis (da Silva et al., 2021).

The future of laboratory diagnostics is likely to see more advancements in technologies and methodologies, with a focus on addressing logistical and infrastructural constraints and limitations. The integration of digital platforms and the optimization of collection and distribution of funds and resources will play a significant role in enhancing community welfare and managing infectious diseases effectively (Ninglasari & Muhammad, 2021).

The long-term implications of the advancements in diagnostics during the pandemic necessitate a holistic approach to future pandemic preparedness and response. The insights gained from various studies and experiences during the pandemic can guide future strategies and interventions to enhance the resilience and responsiveness of healthcare systems and public health policies (Chowdhury et al., 2020).

## **CONCLUSION**

### **Concisely Summarizing the Principal Insights, Findings, and Implications**

The comprehensive review of laboratory diagnostics evolution in Nigeria's response to COVID-19 has provided profound insights into the pivotal role of diagnostics in managing infectious diseases, particularly during a pandemic. The review has meticulously explored the onset and rapid proliferation of COVID-19, initial diagnostic approaches, response strategies, and the imperative of detecting and controlling the spread of infectious diseases. It has also delved into the integral contribution of diagnostics to clinical management and scientific research, providing a holistic perspective on the subject matter.

### **Principal Insights and Findings**

The emergence of COVID-19 in Nigeria and the subsequent response strategies have underscored the significance of laboratory diagnostics in effective pandemic management. The rapid proliferation of the virus necessitated immediate and innovative diagnostic approaches to curb its spread. The advancements in diagnostic procedures, particularly the development of reliable innovative diagnostic tests to detect SARS-CoV-2, have been crucial in managing the pandemic, despite the challenges posed by sampling limitations, especially in settings where large-scale testing of symptomatic and asymptomatic populations are needed (Youngster, 2022).

The review has highlighted the challenges and barriers in diagnostic implementation, including logistical and infrastructural constraints, and regulatory and compliance barriers. The need for dedicated health care workers, fitted with personal protective equipment, has been emphasized, given the time-consuming and expensive nature of sampling, which also exposes health care workers to potential transmission from patients. The exploration of self-sampling for SARS-CoV-2 detection has demonstrated high concordance rates with standard swabs obtained by health care workers, showing that reliable self-sampling using nasal swabs is feasible, even among school-aged children (Youngster, 2022).

The review has also emphasized the multifaceted impact of diagnostic evolution on influencing and shaping effective pandemic management strategies and altering public health policy and practice with enhanced diagnostics. The insights gained from various studies and experiences during the pandemic can guide future strategies and interventions to enhance the resilience and responsiveness of healthcare systems and public health policies.

### **Implications**

The implications of the advancements in diagnostics during the COVID-19 pandemic are extensive and multifaceted. The development and implementation of innovative diagnostic tests have been instrumental in detecting and tracking variants of the virus, enabling the integration of population-based surveillance systems for influenza, SARS-CoV-2, and other respiratory viruses to monitor the spread and intensity of respiratory viruses. The emphasis on strengthening laboratory capacities by the World Health Organization (WHO) underscores the central role of diagnostics in counteracting the pandemic and the need for countries to prioritize contact tracing and quarantining based on WHO recommendations (Youngster, 2022).

The challenges encountered in diagnostic implementation, including logistical and infrastructural constraints, necessitate the development of sustainable strategies and international collaboration to support nations critically deficient in their capacity for pathogenic testing and diagnostics. The lessons drawn from the Ebola outbreak underscore the necessity of strengthening health systems to better respond to future public health crises and the importance of consistent international efforts in building the resilience of health systems in countries experiencing significant morbidity and mortality due to various diseases.

The future of laboratory diagnostics in managing infectious diseases is envisioned to be more integrated, innovative, and crucial in shaping healthcare systems worldwide. The advancements in technologies and methodologies, coupled with the integration of digital platforms and the optimization of the collection and distribution of funds and resources, will play a significant role in enhancing community welfare and managing infectious diseases effectively.

In conclusion, the comprehensive review has provided a holistic perspective on the evolution of laboratory diagnostics in Nigeria's response to COVID-19, offering insightful recommendations for strengthening and enhancing diagnostic capabilities and envisioning the evolving role and future of laboratory diagnostics in managing infectious diseases. The principal insights, findings, and implications derived from this review are instrumental in guiding future strategies, interventions, and research in the field of laboratory diagnostics and infectious disease management.

## **Envisioning the Evolving Role and Future of Laboratory Diagnostics in Managing Infectious Diseases**

The evolving role and future of laboratory diagnostics are pivotal in shaping global health landscapes, particularly in the context of infectious diseases. The advancements and innovations in diagnostic technologies and methodologies elucidated in this review signify a transformative journey in infectious disease management, with a profound impact on public health policies and practices. The integration of enhanced diagnostic procedures, coupled with strategic and sustainable approaches, is crucial in addressing the multifaceted challenges posed by infectious diseases, including logistical, infrastructural, and regulatory barriers.

The future envisions a more resilient and responsive healthcare system, fortified by the lessons learned from the COVID-19 pandemic and previous outbreaks like Ebola. The emphasis on international collaboration, research and development, and strengthening health systems underscores the collective responsibility to enhance global health security. The integration of digital platforms and optimization of resources will be instrumental in fostering more efficient and effective diagnostic implementations, ultimately contributing to improved clinical management, scientific research, and community welfare.

In essence, the future of laboratory diagnostics in managing infectious diseases is poised to be at the forefront of global health innovations, driving transformative changes in healthcare delivery, pandemic preparedness, and response strategies, ensuring a more robust and holistic approach to infectious disease management in the coming years.

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### **Conflict of Interest**

Authors have no conflict of interest to declare.