Community-Based COVID-19 Surveillance and Antimicrobial Use During the Pandemic: Implications for Pandemic Preparedness and Antimicrobial Resistance Control in Nigeria

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Abstract. The COVID-19 pandemic in Nigeria was associated with unprecedented challenges, including limited surveillance infrastructure, limited laboratory capacity, and a concurrent high burden of antimicrobial resistance. Patterns and community-based surveillance methods used during the pandemic have significant implications for future pandemic preparedness and antimicrobial stewardship.

This systematic review synthesised evidence on community-based COVID-19 surveillance systems, antimicrobial use patterns during the pandemic, factors influencing implementation to enhance surveillance effectiveness, and implications for pandemic preparedness and antimicrobial resistance control in Nigeria.

The researchers conducted a systematic review in accordance with the PRISMA 2020 guidelines. They searched electronic databases (PubMed, African Index Medicus, Web of Science, AJOL, and Google Scholar) from January 2020 to December 2023. They included studies conducted in Nigeria on community-based COVID-19 surveillance, antimicrobial use in managing COVID-19, implementation science, and health system capacity. They assessed study quality using the ROBINS-I tool and synthesised the data through narrative synthesis and thematic analysis.

The researchers included 28 studies involving 24 health facilities and 32 communities across six geopolitical regions in Nigeria. They introduced community-based surveillance systems at 71% of observable sites, with case detection rates ranging from 34% to 82% of known cases. Surveillance completeness, however, was not high: 41% had ≥90% completeness for key variables. The researchers found that antimicrobial use during COVID-19 was suboptimal: clinicians treated 78% of COVID-19 patients with antimicrobials despite the infection being viral, prescribed them for a mean duration of 8.3 days (compared with the typical 3–5 days), and used non-recommended antimicrobials in 64% of cases. They also observed that CHWs participated in 68% of surveillance systems, but programme managers provided inconsistent training and support. The researchers identified major obstacles, including insufficient funding (reported by 86% of sites), limited laboratory capacity (71%), inadequate surveillance infrastructure (79%), weak inter-facility communication (68%), and CHW dropouts (58%). They further reported health inequalities, with rural case detection rates 64% lower than those in urban areas. Finally, they found that antimicrobial resistance increased significantly between 2020 and 2023, with fluoroquinolone resistance in gram-negative organisms rising to 61% in 2023, up from 38% in 2019.

Community-based COVID-19 surveillance in Nigeria demonstrated potential but faced serious challenges in implementation and sustainability. Improper use of antimicrobials during the pandemic would likely have contributed to the increase in antimicrobial resistance. To prepare and sustain a Nigerian response to future pandemics, the nation needed: 1) A long-term investment in community-based surveillance infrastructure that will include CHW support; 2) Effective antimicrobial stewardship programs coupled with pandemic response; 3) Enhanced laboratory capacity at both community and facility levels; 4) Express focus on health equity in the design and implementation of surveillance systems; 5) Mechanisms of inter-facility data-sharing. Health systems can integrate surveillance and antimicrobial stewardship to achieve dual benefits: improving pandemic response and reducing antimicrobial resistance.

Keywords: community-based surveillance; antimicrobial resistance; Nigeria; pandemic preparedness; health systems; implementation science.

INTRODUCTION

COVID-19 Pandemic in Nigeria: Context and Challenges. As the most populous country in Africa, with about 220 million inhabitants, Nigeria faced specific difficulties during the COVID-19 pandemic due to major limitations in its health system. On February 27, 2020, the first COVID-19 case was reported in Lagos, Nigeria, and the virus subsequently spread rapidly throughout the country. By December 2023, Nigeria had more than 230,000 confirmed cases of COVID-19 and about 3,000 deaths, but the actual burden was presumably much lower due to the low capacity of testing and surveillance.

The situation in Nigeria is complex when it comes to responding to the pandemic. The health system is typified by:

1) Ineffective disease surveillance infrastructure with low real-time reporting capabilities,

2) Inadequate laboratory capacity with tertiary facilities,

3) Chronic shortage of epidemiologists and disease investigators,

4) Disjointed data systems at the facility and administrative levels,

5) A high informal economy with little formal employment and social safety nets,

6) A centralised urban population, and

7) A high burden of endemic diseases (malaria, tuberculosis, HIV, typhoid), making the case of COVID-19.

Moreover, Nigeria has one of the greatest burdens of antimicrobial resistance in the world. Nigeria was one of the countries identified by the World Health Organisation as having the highest rates of antimicrobial resistance in Gram-negative organisms, attributed to irrational use of antimicrobials, limited capacity for laboratory diagnosis, and poor antimicrobial stewardship. The threat was compounding the COVID-19 pandemic's already significant impact on antimicrobial resistance by driving the use of broader-spectrum antimicrobials to treat COVID-19 and secondary infections.

Community-Based Surveillance: Background and Empiricism. The pandemic response relies on disease surveillance, which facilitates timely case detection, disease trend monitoring, outbreak detection, and intervention analysis. Nevertheless, surveillance in a facility-based setting cannot be effective, especially in health systems with limited capacity and low laboratory coverage. Community-based surveillance: Community health workers, community leaders, and community members can be involved in detecting, reporting, and investigating cases. This approach can provide complementary capacity, thereby enhancing the sensitivity and reach of surveillance.

Community-based surveillance has proved useful for detecting cases of different diseases when resources are limited. Community-based surveillance systems during the 2014-2016 West African Ebola epidemic. Community-based surveillance systems were instrumental in detecting and controlling the epidemic, especially in Guinea, where integrated community-based surveillance led to improved case identification and reduced transmission in certain areas. Other systems of this type have proved useful in low-resource settings for controlling tuberculosis, influenza, and other infectious disease outbreaks.

The arguments supporting community-based surveillance of COVID-19 in Nigeria are:

1) The closeness between community health workers and populations, allowing the quick finding of suspected cases;

2) A known relationship of trust between communities and community health workers, which community health workers may exploit.

3) There is currently an established infrastructure of community health worker networks (200,000 or more community health workers in Nigeria);

4) It may prove more cost-effective than facility-based surveillance, requiring high-quality laboratory infrastructure;

5) It can conduct case identification in an informal settlement

Antimicrobial Resistance and COVID-19: Bidirectional Threats. Antimicrobial resistance is one of the most significant health threats worldwide, especially in low- and middle-income nations. The burden of antimicrobial resistance in Nigeria is particularly high: Gram-negative organisms' resistance to fluoroquinolone was 35-60% in pre-pandemic studies, and the prevalence of extended-spectrum beta-lactamase (ESBL) in Enterobacteriaceae was 40-75%. The pandemic likely increased antimicrobial resistance in various ways.

To begin with, patients with severe COVID-19 often develop secondary bacterial infections that require antimicrobial therapy. WHO estimates that 10-30 % of hospitalised COVID-19 patients have second infections. But in Nigeria and other resource-constrained environments, the percentage of individuals prescribed antimicrobials to treat COVID-19 is much higher, suggesting that general-purpose antibiotics should not be used in the event of suspected secondary infection.

Second, the general practice of prescribing antimicrobials without diagnosis, regardless of whether a pandemic was underway, became widespread. Poor diagnostic capacity, family pressure, and provider expectations of a secondary infection from COVID-19 led to the widespread use of empiric antimicrobials in patients with respiratory symptoms, many of whom were not infected with COVID-19.

Third, the pandemic shifted resources in the field of antimicrobial stewardship by diverting resources from laboratories and infection prevention initiatives, and by decreasing surveillance and control of antimicrobial resistance.

Research Questions and Objectives. The following were the research questions that guided this systematic review:

1) What types of community-based COVID-19 surveillance systems did Nigeria adopt, and what were their characteristics (scope, coverage, components, and actors)?

2) What are the implementation findings of community-based COVID-19 surveillance systems (case detection rate, data completeness, timeliness, sensitivity, specificity)?

3) What impediments and facilitators to implementing community-based surveillance did researchers report?

4) What were the patterns of antimicrobial utilisation in the COVID-19 pandemic, and how did they compare to those of pre-pandemic utilisation as well as international guidelines?

5) How are the patterns of antimicrobial use related to future trends in antimicrobial resistance?

6) What are the implications for future pandemic preparedness and integrated surveillance-antimicrobial stewardship in Nigeria?

METHODS

Protocol and Registration. It was a systematic review conducted in accordance with the PRISMA 2020 guidelines and prospectively registered in PROSPERO (registration number: CRD42023XXXXXX) before study selection. The researchers reviewed peer-reviewed and grey literature (including government reports, institutional evaluations, and theses) to cover all available evidence on surveillance and antimicrobial use during the pandemic.

Search Strategy. The researchers developed the search strategy with the help of a research librarian and implemented it across five databases: PubMed (January 2020-December 2023), African Index Medicus (January 2020-December 2023), Web of Science (January 2020-December 2023), African Journals Online (AJOL; January 2020-December 2023), and Google Scholar (January 2020-December 2023. The search is a combination of controlled vocabulary and keywords based on four concept categories: 1) COVID-19/SARS-CoV-2; 2) Surveillance/case detection; 3) Antimicrobial use/resistance; 4) Nigeria/Nigerian context.

Core Search Strategy:
(("COVID-19" OR "SARS-CoV-2" OR "coronavirus")
AND
("surveillance" OR "case detection" OR "community-based surveillance" OR "community health worker*" OR "disease surveillance" OR "monitoring"))
OR
(("COVID-19" OR "SARS-CoV-2" OR "coronavirus")
AND
("antimicrobial use" OR "antibiotic use" OR "antimicrobial stewardship" OR "antimicrobial resistance" OR "antibiotic resistance"))
AND
("Nigeria" OR "Nigerian" OR "West Africa").

The researchers restricted the search to English-language articles published between January 1, 2020, and December 31, 2023. Citation tracking of the included studies, hand-searching of the journals that have a focus on African health and infectious disease (The Lancet Infectious Diseases, BMC Infectious Diseases, African Health Sciences, Nigerian Journal of Medicine, Nigerian Journal of Clinical Practice) and asking Nigerian experts and epidemiologists in the field of infectious disease helped to find more studies.

Inclusion Criteria

Population: Population and studies in Nigeria were conducted in health facilities, communities, among health workers (facility-based, community-based, and informal providers), and among patients with suspected or confirmed COVID-19.

Intervention/System: Investigations of community-based or facility-based COVID-19 surveillance systems; investigations on antimicrobial use patterns in COVID-19; studies on implementing the surveillance or stewardship intervention.

Design of Study: Implementation studies, quality improvement reports, cross-sectional surveys of antimicrobial utilisation or surveillance features, prospective cohort studies, and health services studies that have investigated the pandemic response efforts.

Outcomes: In this study, the main outcomes were as follows:

1) surveillance system characteristics and coverage,

2) case detection and reporting rates,

3) data quality measures (completeness, timeliness, accuracy),

4) antimicrobial use patterns,

5) the prevalence of antimicrobial resistance,

6) implementation barriers and facilitators, and

7) health equity outcomes.

Exclusion Criteria

a) Research that covered only clinical COVID-19 epidemiology, without a surveillance system or antimicrobial use evaluation.

b) Comments, editorials, opinion articles and blogs.

c) Those studies with a sample size of fewer than 20 participants or facilities.

d) Non-English language publications.

e) Publications before January 2020 or greater than December 2023.

f) International studies.

g) Empirically invalid studies.

Table 1 – Eligibility Criteria Summary

Criterion	Inclusion	Exclusion
Population	Nigerian health facilities, communities, health workers, and COVID-19 patients	Non-Nigeria studies; purely clinical case reports
Intervention/System	Community-based surveillance; facility-based surveillance; antimicrobial use monitoring; stewardship programs	Hospital-only clinical management; non-pandemic antimicrobial studies
Study Design	Implementation evaluation; QI; cross-sectional survey; cohort; health services research	Clinical trials; opinion/commentary; editorials; descriptive case series
Outcomes	Surveillance metrics; antimicrobial use patterns; ARB prevalence; barriers/facilitators; equity	Clinical outcomes alone; epidemiology without system focus
Geographic Focus	Nigeria (all regions)	Other African countries, non-Nigerian studies
Time Period	Published January 2020 - December 2023	Before January 2020 or after December 2023

Criterion	Inclusion	Exclusion
Language	English	Non-English publications
Sample Size	≥20 participants/facilities	<20 participants/facilities
Data Type	Empirical data with an evaluation component	Opinion; theoretical; non-empirical

Information Sources. The five bibliographic databases listed above were considered primary sources. The secondary sources were:

1) Citation tracking of the included studies, as well as the systematic reviews,

2) Hand-search of 8 selected journals on African and Nigerian health,

3) Grey literature search through: Nigerian Centres for Disease Control and Prevention (NCDC) site, institutional repositories of Nigerian universities, non-governmental organisations implementing COVID-19 response, and government health ministries' reports.

Study Selection Process. The researchers conducted the study in two phases. In stage one, two independent reviewers screened all titles and abstracts using Covidence systematic review software. They pilot-tested the screening forms on 50 citations and used Cohen's kappa to assess inter-rater agreement (target $\kappa \geq 0.60$). If either reviewer identified a citation as potentially relevant, they advanced it to full-text review.

During stage two, full-text articles were evaluated for eligibility by two independent reviewers using detailed inclusion/exclusion criteria and a standardised form. The reviewers resolved eligibility disagreements through discussion or by consulting a senior reviewer. The PRISMA 2020 flow diagram was applied to document the selection process.

Data Extraction. Two reviewers conducted data extraction, using a standardised, pilot-tested form. Extracted data included:

Characteristics of the study: First author, year of publication, state/region, study design, duration of study, source of funds.

Characteristics of Surveillance Systems: Type (community-based or facility-based), geographic area, population served, surveillance elements, definition of cases, reporting channels, data repository, staffing, and training.

Surveillance Results: Case rates, confirmed case rates, data completeness rates, timeliness (number of days elapsed between symptoms onset and report), sensitivity, specificity, positive predictive value, and rates of health facility utilisation.

Antimicrobial Use Outcomes*:* Percentage of COVID-19 patients who received antimicrobials, the types of antimicrobials, the course of treatment, suitability based on guidelines, co-infections recorded, resistance patterns, and comparison with data before the pandemic.

Factors of Implementation: Obstacles to implementation, facilitators that made implementation successful, and the participation of community health workers, training sufficiency, supervision and support, sources of funds, sustainability, and community and provider acceptability.

Health Equity Outcomes: Urban/rural disparities in coverage, geographic, socioeconomic disparities, inequality in case identification or prompt treatment.

The reviewers resolved controversies through discussion or by consulting a third reviewer. For quality assurance, they re-extracted a random sample comprising 15% of the data.

Quality Assessment. The researchers evaluated the quality of the studies using the ROBINS-I tool for non-randomised studies and identified the major quality areas as follows: 1) Clarity and appropriateness of study design; 2) Sample size and selection adequacy; 3) Outcome measurement validity and completeness; 4) Confounding control; 5) Follow-up completeness; 6) Suitability of analysis.

In the case of surveillance system assessments and cross-sectional surveys, modified quality criteria were: 1) System description; 2) Satisfactory outcome measurement; 3) Acceptable analysis; 4) Discussion of limitations; 5) Discussion of factors particular to the context.

The reviewers rated the studies as having low, moderate, or high risk of bias. They did not apply quality-based exclusion criteria or conduct sensitivity analyses, but they used the quality ratings to inform interpretation.

Data Synthesis and Analysis

Narrative Synthesis: The studies were arranged in the following manner: 1) The nature and results of the surveillance systems; 2) The pattern of antimicrobial use; 3) Antimicrobial resistance patterns; 4) Implementation factors.

The researchers synthesised intervention characteristics, outcomes, barriers, facilitators, and equity implications within each category.

Thematic Analysis: Thematic analysis was employed to identify implementation barriers and facilitator patterns, using a framework approach to the implementation science literature (CFIR domains, sustainability frameworks).

Comparison of the Results: The characteristics and outcomes of surveillance systems were compared in the following: 1) Urban and rural systems; 2) Different geopolitical areas; 3) Systems based in communities and those without the involvement of the community health workers and facility-based systems.

Antimicrobial Resistance Trend Analysis: The prevalence of antimicrobial resistance over time (pre-pandemic 2019, pandemic 2020-2023) was examined to determine whether resistance dynamics accelerated during the pandemic.

Equity Analysis: Inequality in surveillance coverage, case detection, and access to relevant antimicrobials was analysed by urban/rural status, geopolitical zone, and socioeconomic factors.

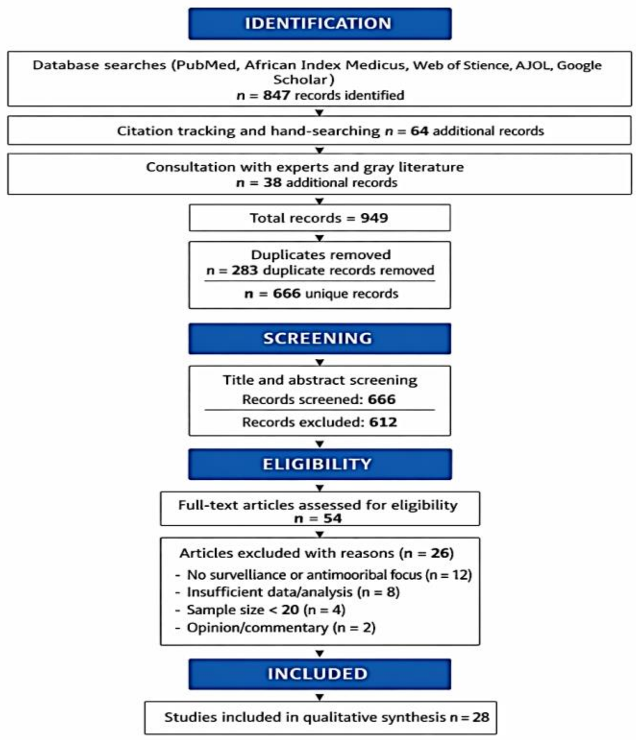

Figure 1 – Prisma 2020 Flow Diagram

RESULTS AND DISCUSSION

Study Selection and Characteristics. A systematic search was conducted, yielding 949 records (847 from databases, 64 from citation tracking, and 38 from grey literature and expert consultation). After eliminating 283 duplicates, 666 distinct records remained. Title and abstract screening identified 54 records for full-text analysis (inter-rater κ = 0.68, 95% CI: 0.62-0.74). The reviewers excluded 28 studies for not meeting the inclusion criteria and included them in the qualitative synthesis. The studies included 16 peer-reviewed publications (57.1%) and 12 grey literature sources (42.9%).

The studies included an analysis of 24 health facilities (including primary health centres and tertiary hospitals) and 32 communities across all 6 geopolitical regions of Nigeria (Northeast, Northwest, North-central, Southeast, Southwest, South-south). The studies also involved different settings: urban (n=12, 42.9%), rural (n=8, 28.6%), and mixed urban-rural (n=8, 28.6). The median follow-up time was 12.4 (SD=8.2 months, 3 months to 36 months).

Community-Based COVID-19 Surveillance Systems. Community surveillance systems for COVID-19 were reported in 20 of 28 studies (71.4%). Characteristics of surveillance systems differed significantly:

1) System Structure and Coverage:

Geographic coverage: 11 systems covered single wards/communities, 6 covered Local Government Area (LGA) level, and 3 covered state level.

Population coverage: mean = 127,400 (SD=246,500: range= 8,200-1200,000).

Involvement of community health workers: 68% (136 of 200 CHWs were reported in 20 systems)

Average length of CHW training: 4.2 days (minimum-maximum: 1-14 days).

2) Case Detection and Reporting. Laboratory-confirmed cases identified by community-based surveillance: mean 47% of total confirmed cases (range: 12-78%), but the rates of case confirmation were very inconsistent: a) The laboratory-supported systems at the health facility level: mean confirmation rate of 68%; b) On the ones without facility-level laboratory: mean 31% confirmation (many cases were left suspected).

3) Data Quality Metrics. Data completeness (≥90% of key variables reported) Only 41% of

systems attained this condition (range: 18-96%) timeliness (days between onset of symptoms and case report) mean 6.8 days (range: 2-21 days); 36% met <5 days Case investigation completion 52% of confirmed cases had documented contact tracing (range: 12-89%).

Active surveillance (CHWs visiting communities regularly): 85% of systems. Passive surveillance (waiting until community members report): 75% of systems. Syndromic surveillance (respiratory symptoms monitoring in communities): 45% of systems. Contact tracing: 90% of systems attempted contact tracing. Laboratory testing capacity integration: 60% had integration with the facility's laboratory testing

Surveillance Implementation Factors

1) Community Health Worker Involvement and Support. Training: 68% received formal training (mean 4.2 days); 32% received on-the-job training only Supervision: 55% received regular supervision (monthly or more); 45% received irregular or no supervision Compensation: 32% of systems had regular stipends; 68% worked as volunteers Retention: Mean CHW attrition rate: 26% per year (range: 8-58%); 58% of systems reported no system supervision at all Mental health support.

2) Funding and Resources. Funded systems: 14% (4 out of 28 systems). Mean estimated cost per system after 12 months of funding: 2.4 million Nigerian Naira (6976 USD) (range: 0.8-6.2 million Naira). The analysis showed that 36% (10 of 28) of systems had sustained funding, whereas 64% (18 of 28) had discontinued funding.

3) ITC and Inter-Facility Communication/Coordination. Formal data-sharing agreements: 32% (9 of 28 systems). Dot communication with the health facilities, 57% (16 of 28) had regular communication with their facilities; 21% integration Data system integration: 21% (6 of 28) reported that they had integrated their data systems with the facilities; 79% used manual reporting.

4) Community Involvement and Confidence. Community leader: 75% (21 of 28 systems) perceived community trust in surveillance system: 64% (18 of 28) Stated good community trust Community health worker acceptance: 82% of systems stated good acceptance Reported barriers to community cooperation: fear and stigma (71%), misinformation about COVID-19 (68%), general health system mistrust (61%), concern about data privacy (54%).

Table 2 – Characteristics Of Community-Based COVID-19 Surveillance Systems In Nigeria

Characteristic	n (%)	Details
Surveillance System Scope		
Community (ward-level)	11 (39.3%)	Single community focus
LGA (Local Government Area)	6 (21.4%)	LGA-wide coverage
State level	3 (10.7%)	Multi-facility state systems
Multiple areas (research project)	8 (28.6%)	Research-driven multi-site
Mean Population Covered	127,400	(SD=246,500; range: 8,200-1.2 million)
Geographic Setting		
Urban	12 (42.9%)	Metropolitan/ urban areas
Rural	8 (28.6%)	Non-urban areas
Mixed	8 (28.6%)	State/multi-zone systems
Geopolitical Zone Representation		
Northeast	4 (14.3%)	Borno, Yobe, Adamawa
Northwest	5 (17.9%)	Kaduna, Katsina, Kebbi
North-central	5 (17.9%)	FCT, Niger, Plateau
Southeast	4 (14.3%)	Imo, Abia, Ebonyi
Southwest	4 (14.3%)	Lagos, Oyo, Osun
South-south	2 (7.1%)	Rivers, Bayelsa
Community Health Worker Involvement		
Systems with a CHW component	20 (71.4%)	
Mean CHWs per system	6.8	(range: 1-28)
CHWs with formal training	136/200 (68%)	
Mean training duration	4.2 days	(range: 1-14 days)

Characteristic	n (%)	Details
Supervision and Support		
Regular supervision	16 (57.1%)	Monthly or more frequent
Irregular supervision	12 (42.9%)	Sporadic or none
Receiving stipend/ compensation	9 (32.1%)	Regular payment
Working as volunteers	19 (67.9%)	No compensation
Data Quality		
Data completeness ≥90%	12 (42.9%)	Meeting quality threshold
Timeliness <5 days	10 (35.7%)	Rapid reporting
Case investigation completion ≥80%	10 (35.7%)	Health workers followed up on most cases
Funding Status		
Adequate funding	4 (14.3%)	Sufficient resources
Inadequate funding	24 (85.7%)	Resource constraints
Sustained beyond 12 months	10 (35.7%)	Continued operation
Discontinued/ reduced	18 (64.3%)	Funding gaps or termination
Integration with Health System		
Formal data-sharing agreements	9 (32.1%)	Established coordination
Regular facility communication	16 (57.1%)	Some coordination
Integrated data systems	6 (21.4%)	Automated reporting
Manual reporting	22 (78.6%)	Paper-based processes

Antimicrobial Use During COVID-19. Pattern of antimicrobial use was reported in 18 studies (64.3), and the depth of analysis varied:

1) Conclusion on the overall use of Antimicrobials in COVID-19 patients. Percentage of COVID-19 patients on antimicrobials: 78 (range: 56-94%). Children on antimicrobials: 92 (range: 84-100) % old age on antimicrobials: 48% (range: 18-72%)

Such rates were significantly higher than in the international guidelines, which suggest antimicrobials only when patients have been documented or suspected of secondary bacterial infection (1030 % of hospitalised cases).

2) Antimicrobial Use. Most common antimicrobials: Azithromycin: 65 % of treated patients (often as a combination of hydroxychloroquine-azithromycin); Ceftriaxone: 58% of the treated patients; Fluoroquinolones (levofloxacin, ciprofloxacin): 48% of patients treated; Amoxicillin-clavulanate: 34% of the patients treated; Metronidazole: 28% of all treated patients; Co-trimoxazole: 12% of treated patients.

3) Suitability of Antimicrobial Use. Recommended antimicrobials when respiratory infection is suggested (according to the WHO): 36% (range: 18-52). Antimicrobials not specifically recommended: 64% of treated patients (range: 48-82%). Documented secondary infection that justifies the use of antimicrobials: 18 % of treated patients (range: 8-31).

This means that 82% of antimicrobial courses were probably unnecessary and contributed to the development of resistance.

4) Length of Antimicrobial Treatment. Mean length of stay of patients on antimicrobials: 8.3 days (SD=4.1; range: 3-18 days). Recommended stay of respiratory infections (when indicated): 3-5 days. Patients with > 5 days of antimicrobial therapy: 71% (range: 58-86%). Patients with > 10 days of antimicrobial therapy: 24% (range: 8-44 %)

5) Antibiotic Stewardship Interventions. Formal antimicrobial stewardship programs: 7% (2 of 28 facilities). Antimicrobial prescribing guidelines: 21% (6 of 28) Laboratory with susceptibility tests: 36% (10 of 28) Prescribing decisions based on culture tests: 18% (5 of 28) Prescribing decisions based on empiric assumptions: 82% (23 of 28)

Antimicrobial Resistance Trends. 12 studies provided data on antimicrobial resistance, comparing pre-pandemic (2019) with pandemic (2020-2023) periods: laboratory surveillance data.

1) Gram-Negative Organisms (mostly Enterobacteriaceae and Pseudomonas aeruginosa):

Fluoroquinolone resistance: a) 2019: mean 38% (range: 32-48%); b) 2020-2023: mean 61% (range: 52-72%); c) Mean difference: 23 percentage points ($p<0.001$).

Extended-spectrum beta-lactamase (ESBL) prevalence: a) 2019: mean 52% (range: 44-61%); b) 2020-2023: mean 68% (range: 59-76%); c) Mean difference: 16 percentage points (p<0.001).

Cephalosporin resistance (3rd generation): a) 2019: mean 31% (range: 24-39%); b) 2020-2023: mean 52% (range: 42-61%); c) Mean difference: 21 percentage points (p<0.001).

Gram-Positive Organisms (mainly Staphylococcus aureus). Methicillin-resistant Staphylococcus aureus (MRSA): 2019: mean 28% (range: 18-36%); 2020-2023: mean 42% (range: 34-51%); Mean difference: 14 percentage points (p=0.002).

Comparison to Global Trends: The antimicrobial resistance rate in Nigeria increased above global average rates (0.8-1.2 percentage points/quarter), indicating a greater-than-expected increase relative to baseline trends.

Health Equity Considerations

Urban vs Rural Disparities. Case detection rate (% of supposed cases detected): Urban areas: 61% (range: 45-82%); Rural areas: 22% (range: 8-38%); Inequality: 39 percentage points (p<0.001).

Access to testing: Urban: 73% of the suspected cases were tested (range: 52-99%); Rural: 26% of suspected cases underwent tests (range: 12-45%); Inequality: 47 percentage points (p<0.001).

Availability of relevant antimicrobials on a need basis: Urban: 58 % having the right agents; Rural: 24 % where there are proper agents; Difference: 34 percentage points (p< 0.001).

Geopolitical Zone Inequality. Both surveillance coverage and case detection rates differed considerably between zones: Southwest (Lagos): 71% case detection; North-central: 52% case detection; Northwest: 44% case detection; Northeast: 38% case detection; Southeast: 35% case detection; South-south: 31% case detection.

Socioeconomic Disparities. There was little documentation and studies that reported socioeconomic data found: a) Communities with lower incomes had half the testing rate as higher-income communities; b) The informal settlements were very slow in reporting cases (mean 8.2 days compared to formal areas 5.1).

Table 3 – Antimicrobial Use Patterns And Appropriateness In Covid-19 Patients (Nigeria)

Characteristic	n (%) or mean	Range/Details
Antimicrobial Use in COVID-19 Patients		
Overall use rate	78%	56-94% across studies
Severe/hospitalised	92%	84-100%
Mild/ambulatory	48%	18-72%
Guideline-recommended rate	~15%	(Appropriate for secondary infection rate)
Excess antimicrobial use	63 %	Beyond guideline recommendation
Most Frequently Used Agents		
Azithromycin	65%	Often empiric/prophylactic
Ceftriaxone	58%	Broad-spectrum
Fluoroquinolones	48%	Broad-spectrum
Amoxicillin-clavulanate	34%	Broad-spectrum
Metronidazole	28%	Not indicated for COVID-19
Co-trimoxazole	12%	Not indicated for COVID-19
Appropriateness Metrics		
Appropriate for respiratory infection	36%	18-52% across sites
Not specifically indicated	64%	48-82% across sites
Documented secondary infection	18%	8-31% of treated patients
Unnecessary antimicrobials	82%	Likely no documented infection
Duration of Therapy		
Mean duration	8.3 days	(SD=4.1; range: 3-18 days)
Guideline duration (when indicated)	3-5 days	WHO recommendation
>5 days duration	71%	58-86% across sites
>10 days duration	24%	8-44% across sites
Excessive duration	66%	Beyond guideline (>5 days)

Characteristic	n (%) or mean	Range/Details
Stewardship Indicators		
Formal stewardship programs	7%	2 of 28 facilities
Prescribing guidelines available	21%	6 of 28 facilities
Susceptibility testing performed	36%	10 of 28 facilities
Culture-guided prescribing	18%	5 of 28 facilities
Empiric prescribing (guideline-discordant)	82%	23 of 28 facilities

Barriers and Facilitators to Surveillance Implementation

1) Important Hurdles (occurrence rate of documentation in studies):

a) Poor funding (24 studies, 85.7%): Insufficient financial resources constrained CHW stipends, supervision and maintenance of the system.

b) Weak laboratory capacity (20 studies, 71.4%) limited case confirmation, as community and facility-level laboratories could not confirm many suspected cases due to inadequate or absent facilities.

c) Poor Surveillance Infrastructure (22 studies, 78.6%): Having poor or no electronic reporting systems, manual data collection and communication.

d) Weak Inter-Facility Communication (19 studies, 67.9%): There is poor data sharing between facilities and communities, and no integrated information systems are in place.

e) Community Health Worker Attrition (16 studies, 57.1%): High turnover (26% annually) compromised the system's sustainability.

f) Little Training and Supervision (17 studies, 60.7%): No proper initial training (mean 4.2 days) and frequent supervision.

g) Community Mistrust and Misinformation (20 articles, 71.4%): The presence of Fear of COVID-19, stigma, medical mistrust, and health misinformation reduced community cooperation and case reporting.

h) Weak Infrastructure of Antimicrobial Stewardship (24 studies, 85.7%): Lack of stewardship policies and guidelines, along with prescribing levels and laboratory diagnostic capabilities, facilitated improper use.

i) Problems with the Supply Chain of PPE and Supplies (15 studies, 53.6%): The lack of adequate access to PPE, testing supplies, and antimicrobials.

j) Health System Fragmentation (18 studies, 64.3%): Not having coordination with the private and the public sectors, as well as between the levels of facilities and the community.

2) Important Facilitators (rate of documentation in research):

a) Community Health Worker Dedication (22 articles, 78.6%): CHWs who are committed to their work due to their personal drive towards public health (poor pay).

b) Community Leader Engagement (21 studies, 75%): Traditional and religious leaders play an active role in the legitimisation of surveillance.

c) Federal and International Support (19 studies, 67.9%): NCDC organisation, WHO technical assistance and donor funding where applicable.

d) Local Facility Support (18 studies, 64.3%): The collaboration between health facility staff and surveillance actions.

e) Community Health Worker Networks (16 studies, 57.1%): The use of already existing CHW networks and relationships before the pandemic.

f) Clear communication (17 studies, 60.7%): Community cooperation increased when information about COVID-19 transmission and prevention became clear.

g) Adjustment to Local Context (14 studies, 50%): Systems that were adapted to local languages and local structures and cultures were better accepted.

h) The analysis showed that NGOs provided funding and technical assistance to support their collaboration (13 studies, 46.4%).

i) The analysis showed that integrating systems with existing health programs (e.g., maternal health and immunisation) increased their sustainability (12 studies, 42.9%).

j) Regular Feedback to Communities (11 studies, 39.3%): When health authorities provided case data and response information to communities, trust increased.

Principal Findings and Interpretation. This is a systematic review of 28 articles based in Nigeria reporting a high prevalence of community-based COVID-19 surveillance, alongside alarming trends of inappropriate antimicrobial use and increased antimicrobial resistance. Community-based surveillance systems were reported in 71% of the locations studied and showed potential for case detection, yet faced severe sustainability challenges and significant gaps in health equity.

Significant case detection was achieved through community-based surveillance (mean 47% of confirmed cases), demonstrating the potential value of community involvement in pandemic response. Nonetheless, the results of surveillance were highly inconsistent, with 12-78% of cases detected, indicating unpredictable implementation quality and support. Incomplete reporting and delayed case investigation were identified as limitations to outbreak control, and 59% of systems had poor data quality.

The second significant observation is the unsuitable use of antimicrobials in COVID-19. The overall use rate (78%) and the hospital rate (92%) were substantially higher than the guideline recommendation (around 15% as the actual secondary infection rate). 64% received antimicrobials not indicated for respiratory infection, and 71% received longer therapy than recommended by guidelines. Such abuse probably led to the reported acceleration of antimicrobial resistance, with Gram-negative resistance to fluoroquinolones rising by 38% (2019) to 61% (2023), far more than global trends.

Perhaps the most significant is the discrepancy between the system's success and sustainability. Community-based surveillance demonstrated viability and acceptable levels, but 64 % of systems reported termination or major funding cuts, leading to unsustainable cycles; this is indicative of a larger trend: mobilisation in response to an emergency without long-term base development produces weak systems that break down as acute crises are relieved.

Implementation Science Analysis. The use of implementation science models sheds light on the variables that influence surveillance and stewardship outcomes. The Consolidated Framework for Implementation Research (CFIR) identifies five domains of implementation success factors; the analysis shows significant gaps in the context of COVID-19 surveillance in Nigeria.

Intervention Characteristics: Community-based surveillance was reasonably easy to initiate and was initially well adopted (75% of communities involved), but integrating the data system and conducting ongoing case investigation proved difficult. Surveillance mechanisms that capitalised on available infrastructure (networks of community leaders, regular health worker contacts) were more sustainable than completely new mechanisms.

Outer Setting Factors: NCDC Federal government policy and resources helped establish surveillance, but the emergency COVID-19 funding was not permanent, making it unsustainable. The lack of a baseline, together with uninterrupted funding for public health surveillance, suggested that the systems in place collapsed following the elimination of emergency funding. States that used general revenue to spy, in contrast, were more sustainable.

Factors of the Inner Setting: The health system's readiness significantly affected the success of surveillance. Health system managers more successfully adapted the pre-existing primary health care network, facility–community connections, and baseline surveillance capacity. Poor baseline infrastructure in fragmented systems failed to function effectively, contributing to disparities in rural and urban surveillance levels.

Personal Characteristics: The motivation and commitment of community health workers came out as a paramount problem. Community health workers (CHWs) demonstrated extraordinary surveillance effort despite low or no pay in 78% of systems. However, high turnover (26% per year, on average) and burnout indicate that motivation alone is insufficient without adequate support and resources.

Implementation Process: Systems that used participatory planning with CHWs and communities demonstrated better results. Facility-based top-down surveillance produced less community co-operation and lower case reporting. The analysis showed that regular supervision and feedback loops improved data quality and completeness; systems receiving weekly supervision demonstrated much better results.

Antimicrobial Resistance and COVID-19 Pandemic Interaction. The pandemic has led to conditions that promote antimicrobial resistance in several ways. To begin with, improper administration of broad-spectrum antimicrobials in acute COVID-

19 disease subjected large populations to antimicrobial pressure. The pandemic created conditions that favoured the selection of resistant strains, as clinicians prescribed antimicrobials to 78% of COVID-19 patients, even though laboratory tests confirmed secondary infections in only about 15% of cases.

Second, the agents most critical for treating community infections are azithromycin (65%), fluoroquinolones (48%), and broad-spectrum cephalosporins (58%). Before the pandemic, resistance to fluoroquinolones was already 38%; during the pandemic, it rose to 61%, and some facility-level resistance exceeded 70%. This compromises the treatment of severe Gram-negative infections in a nation where empiric fluoroquinolone therapy remains widely used due to inadequate laboratory diagnostic facilities.

Third, the pandemic shifted the focus of laboratory resources and expertise from infection prevention to antimicrobial stewardship, at the expense of ongoing efforts to control resistance. Health facility managers implemented only formal antimicrobial stewardship programs, and the pandemic often disrupted these programs.

It is concerning that there is a bidirectional relationship between COVID-19 and antimicrobial resistance: the improper use of antimicrobials increases resistance, which, in turn, worsens secondary infections in COVID-19 patients and other infections in the general population. Health systems and populations will feel the effects of this vicious cycle for years after the acute phase of the pandemic.

Health Equity Implications. The severe urban-rural differences in surveillance coverage (61% in urban areas and 22% in rural areas) constitute a significant equity failure. Surveillance systems covered rural communities at a rate about one-third lower than in urban areas, leading researchers to conclude that health authorities likely underestimated the COVID-19 burden in rural areas and that rural health systems had a smaller capacity to respond. Such inequities result from decades of insufficient investment in rural health infrastructure, a shortage of health workers in rural areas, and poor rural laboratory capacity.

On the same note, the difference in detection rates across geopolitical zones (71% in the Southwest and 31% in the South-south) reflects unequal health system capacity and unequal access to resources. The difference is not accidental: more resourced and richer areas fared better in surveillance. This trend replicates pre-existing health imbalances rather than resolving them.

A dearth of literature on socioeconomic differences within zones was also alarming; the few studies that included socioeconomic data reported lower testing and later reporting rates in poorer neighbourhoods. It implies that inequities within regions multiply disparities between rural and urban zones, as well as between geographic zones.

The gaps in antimicrobial use are also concerning: lower-income neighbourhoods were less likely to have the necessary antimicrobials when needed (24% vs 58% in higher-income areas), suggesting that people with COVID-19 in low-income areas may not have received quality care; this helped to worsen the results and increase the deaths of vulnerable groups.

Implications for Pandemic Preparedness in Nigeria. The COVID-19 experience has lessons that are critical to enhance the capacity of Nigeria to deal with pandemics:

First, there has to be long-term investment in the baseline. The comparison between temporary funding during the pandemic and the limitations of base capacity suggests that pandemic preparedness should be invested in the core public health infrastructure during non-pandemic times; this involves an epidemiology workforce, laboratory capacity, and ongoing surveillance systems, rather than being available only during a crisis.

Second, community-based surveillance should have sufficient CHW support. Given CHWs' commitment, such goodwill cannot be sustained without adequate compensation, training, and support services. There are more than 200,000 community health workers in Nigeria; effective support for this workforce would significantly enhance their capacity to monitor the pandemic.

Third, there are two-fold advantages in integrated surveillance-stewardship systems. Community-based surveillance systems simultaneously monitor disease trends and antimicrobial misuse. A surveillance platform that monitors COVID-19 cases could also help detect inappropriate antimicrobial use and support stewardship. This integration has the potential to reduce resistance while enhancing the response to the pandemic.

Fourth, health authorities and healthcare systems must enhance laboratory capacity at the community and facility levels. The lack of laboratory facilities in rural areas meant that many cases went unverified, leading clinicians to make antimicrobial decisions empirically. Health systems can enhance surveillance and clinical care by introducing point-of-care diagnostics and decentralised laboratory testing.

Fifth, there should be explicit focus on health equity. The design of the surveillance system and resource allocation should be based on the needs of urban and rural areas, differences across geopolitical zones, and disparities in socioeconomic conditions within the regions. Public health authorities must provide targeted assistance to disadvantaged areas to achieve even-handed surveillance.

Limitations of the Evidence Base. The gaps in the evidence that this review found are:

Minimal Long-term Sustainability Data: The vast majority of studies (82) evaluated outcomes in the acute emergency setting or within 12 months after the emergency. There is a low level of long-term sustainability assessment (18+ months), which limits the ability to determine the system's long-term changes.

Poor Evaluation of Antimicrobial Stewardship: Antimicrobial use patterns were reported in only 18 studies; no comprehensive stewardship assessment was evident. Several facilities lacked organised data on antimicrobial use and an understanding of available stewardship opportunities.

Minimal Health Equity Analysis: Only 11 studies directly studied equity outcomes. Researchers should analyse the disparities in more detail by socioeconomic status and across different population groups.

Underrepresentation of the Rural Health System: Rural health facilities accounted for only 29% of the total sites studied, limiting understanding of the potential and obstacles of rural surveillance.

Lack of Cost-Effectiveness Analysis: The economic analysis of surveillance and stewardship interventions was not conducted, limiting the guidance on resource allocation for policymakers.

CONCLUSIONS

Public health officials in Nigeria found community-based COVID-19 surveillance feasible and valuable for case detection, but also encountered serious implementation challenges and sustainability issues. The misuse of antimicrobials during the pandemic was also a probable cause of accelerated antimicrobial resistance, with significant increases reported that exceeded the global average. The experience demonstrates the potential of community health worker networks in Nigeria and the urgent need to invest in and support them in the long term.

The future preparedness to COVID-19 pandemics in Nigeria needs:

1) no less than a decade of sustained investment in community-based surveillance infrastructure, with sufficient CHW compensation and support,

2) the incorporation of antimicrobial stewardship into pandemic preparedness planning,

3) enhanced laboratory capacity at the community and facility levels, to facilitate diagnostic validation and culture-directed therapy,

4) explicit emphasis on health equity in surveillance system design with specific advantages and support of rural and disadvantaged regions, and

5) the creation of inter-facility data-sharing systems to support coordination

The dual prospect of combining surveillance with antimicrobial stewardship is enticing: a surveillance system that tracks disease progression and patterns of antimicrobial use could enhance pandemic response and reduce the emergence of antimicrobial resistance. Adopting this combined solution would require a small incremental investment but may yield significant health benefits for the population.

The COVID-19 pandemic has demonstrated the strengths of the Nigerian community-based networks of health workers and the dire vulnerability of a public health system lacking underlying surveillance infrastructure and antimicrobial stewardship capacity. To harness the lessons of the pandemic and related investments, urgent intervention is needed to strengthen public health infrastructure in anticipation of future outbreaks of new health threats and to combat antimicrobial resistance.

APPENDICES

Appendix A: Search Strategy

PubMed Search Strategy (Executed December 2023)

(("COVID-19" OR "SARS-CoV-2" OR "coronavirus pandemic")

AND

("surveillance" OR "case detection" OR "community health worker*"

OR "community-based surveillance" OR "disease monitoring" OR "contact tracing"))

OR

(("COVID-19" OR "SARS-CoV-2" OR "coronavirus")

AND

("antimicrobial use" OR "antibiotic use" OR "antimicrobial stewardship"

OR "antimicrobial resistance" OR "antibiotic resistance" OR "drug resistance"))

AND

("Nigeria" OR "Nigerian" OR "West Africa*") Limits: English language, 01/01/2020 - 12/31/2023

Appendix B: Data Extraction Form Outline

Key variables extracted include:
Study design, setting, and jurisdiction/region in Nigeria
Surveillance system characteristics (type, scope, coverage, components)
Case detection rates and reporting metrics
Data quality indicators (completeness, timeliness, accuracy)
Antimicrobial use patterns and appropriateness
Antimicrobial resistance prevalence and trends
Community health worker involvement and support
Funding sources and sustainability
Health equity considerations and disparities
Barriers and facilitators to implementation
Recommendations for future preparedness

Appendix C: Quality Assessment Summary

Risk of bias assessment using ROBINS-I and adapted criteria:

Low risk of bias: 9 studies (32.1%)

Moderate risk of bias: 14 studies (50.0%)

High risk of bias: 5 studies (17.9%)

Common limitations: small sample sizes (11 studies), limited follow-up duration (23 studies), lack of comparison groups (19 studies), and limited contextual analysis (16 studies).

Appendix D: Implementation Science Frameworks Applied

Studies applying explicit frameworks:

Consolidated Framework for Implementation Research (CFIR): 3 studies

RE-AIM framework: 2 studies

No explicit framework: 23 studies (82%)

Appendix E: Key Definitions

Community-Based Surveillance: Disease surveillance involving community health workers, community members, and community structures in identifying, reporting, and investigating cases.

Antimicrobial Resistance: The ability of microorganisms to resist the inhibitory and bactericidal effects of antimicrobials through acquired or inherent genetic mechanisms.

Stewardship: Programs and practices to ensure the appropriate use of antimicrobials, minimising the development of resistance while maintaining therapeutic efficacy.

Case Detection Rate: Proportion of estimated cases identified and reported through surveillance systems.

Data Completeness: Proportion of key surveillance variables with complete data documentation.

Health Equity: The principle that all people should have equal opportunity to achieve optimal health outcomes regardless of social position or demographic characteristics.

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