World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

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Rubella burden hidden within measles case-based Surveillance in Rivers State, Nigeria: A Retrospective Comparative Analysis

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World Journal of Advanced Research and Reviews, 2026, 30(03), 1341-1350

Publication history: Received on 09 May 2026; revised on 15 June 2026; accepted on 17 June 2026

Article DOI: https://doi.org/10.30574/wjarr.2026.30.3.1703

Abstract

Background: Rubella remains an under-recognized vaccine-preventable disease in many low- and middle-income countries, including Nigeria, where routine rubella vaccination coverage remains suboptimal. In many African countries, rubella surveillance is conducted through integrated measles case-based surveillance systems, leading to undetected rubella transmission among suspected measles cases. This study assessed the burden and epidemiological characteristics of rubella identified within measles surveillance data in Rivers State, Nigeria.

Methods: A retrospective comparative analysis of measles case-based surveillance data from Rivers State, Nigeria, was conducted using laboratory surveillance records from January 2020 to December 2024. Data were extracted from the integrated measles-rubella surveillance database and analyzed using Statistical Package for Social Sciences (SPSS) version 25. Laboratory-confirmed measles and rubella cases were identified using measles immunoglobulin M (IgM) and rubella IgM serology results. Descriptive statistics were used to summarize demographic and temporal characteristics. Comparative analyses were performed using the Chi-square and Mann–Whitney U tests, and logistic regression was used to identify factors associated with rubella positivity among measles-negative suspected cases. Statistical significance was set at $p<0.05$.

Results: A total of 1,520 suspected febrile rash illness cases were analyzed during the study period. Of these, 297 (19.5%) were laboratory-confirmed measles cases, while 102 (6.7%) were laboratory-confirmed rubella cases. Among the 1,172 measles-negative cases, 102 (8.7%) were positive for rubella IgM, demonstrating a hidden but measurable burden of rubella within the measles surveillance system.

The median age of measles-confirmed cases was 10.5 years (IQR: 4–25 years), compared with 7 years (IQR: 4–18 years) among rubella-confirmed cases ($p=0.031$). Males constituted 54.9% of measles-confirmed cases and 49.0% of rubella-confirmed cases. Measles positivity peaked in 2022, while rubella transmission persisted throughout the study period.

In the multivariable logistic regression analysis, age less than 15 years was independently associated with rubella positivity among measles-negative suspected cases (AOR: 1.69; 95% CI: 1.02–2.81; $p=0.041$).

Conclusion: A hidden but measurable burden of rubella exists within measles case-based surveillance in Rivers State, Nigeria. Persistent rubella transmission among measles-negative febrile rash illness cases underscores the importance of integrated measles-rubella surveillance systems and strengthened laboratory confirmation. The findings support enhanced rubella surveillance, improved routine immunization strategies, and accelerated scale-up of rubella-containing vaccines in Nigeria.

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Keywords: Rubella; Measles; Surveillance; Vaccine-preventable diseases; Rivers State; Nigeria; Integrated surveillance; Febrile rash illness

1. Introduction

Measles and rubella remain major vaccine-preventable viral diseases of global public health importance despite the availability of safe and effective vaccines for several decades. Measles is caused by a Morbillivirus belonging to the family Paramyxoviridae and is characterized by fever, generalized maculopapular rash, cough, coryza, and conjunctivitis. Rubella, also known as German measles, is caused by a Togavirus of the genus Rubivirus and usually presents as a mild, febrile, rash-associated illness in children and adults. However, rubella infection during pregnancy, particularly during the first trimester, may result in congenital rubella syndrome (CRS), leading to miscarriage, stillbirth, congenital cataracts, deafness, cardiac malformations, and neurodevelopmental abnormalities [1–3].

Globally, substantial progress has been made toward reducing measles mortality and eliminating measles through improved vaccination coverage and strengthened surveillance systems. The World Health Organization (WHO) estimated that measles vaccination prevented approximately 57 million deaths worldwide between 2000 and 2022 [4]. Despite this progress, measles outbreaks continue to occur in several low- and middle-income countries due to persistent immunity gaps, poor vaccination coverage, conflict, population displacement, vaccine hesitancy, and disruptions in routine immunization services [5,6].

In sub-Saharan Africa, measles remains endemic in many countries, including Nigeria, where periodic outbreaks continue to occur despite intensified immunization campaigns and supplementary immunization activities [7]. Nigeria contributes substantially to the regional burden of measles due to its large population, heterogeneous vaccination coverage, and surveillance challenges [8]. Studies have shown that measles transmission persists, particularly in underserved and hard-to-reach populations where immunization coverage remains suboptimal [9].

Rubella epidemiology in Africa remains less characterized compared with measles because many countries rely on integrated measles-rubella surveillance systems rather than stand-alone rubella surveillance programs [10]. In many African countries, including Nigeria, suspected measles cases that test negative for measles immunoglobulin M (IgM) antibodies are subsequently tested for rubella IgM antibodies. Consequently, a substantial proportion of rubella infections may remain hidden within measles surveillance systems and therefore under-recognized by policymakers and public health authorities [11].

Although rubella infection is generally mild in children, its public health significance lies primarily in congenital rubella syndrome. WHO estimates suggest that more than 100,000 infants are born annually worldwide with CRS, predominantly in countries without widespread rubella vaccination programs [12]. The burden of CRS in Nigeria is believed to be underreported because surveillance systems for congenital rubella remain weak, and laboratory confirmation capacity is limited [13].

Integrated measles-rubella surveillance has become an important strategy for monitoring vaccine-preventable rash illnesses in low-resource settings. The WHO African Regional Office recommends case-based surveillance for all suspected measles cases with laboratory confirmation through serological testing [14]. This integrated surveillance approach allows countries to monitor both measles and rubella circulation simultaneously using shared infrastructure, thereby improving efficiency and reducing surveillance costs [15].

Nigeria operates an Integrated Disease Surveillance and Response (IDSR) system coordinated by the Nigeria Centre for Disease Control and Prevention (NCDC), which includes case-based surveillance for measles and rubella [16]. Surveillance activities involve case detection, specimen collection, laboratory confirmation, data management, and outbreak response. Rivers State, one of the most populous and urbanized states in southern Nigeria, has strengthened disease surveillance systems over the years through collaboration between the Rivers State Ministry of Health, healthcare facilities, and international partners.

Despite improvements in surveillance systems, limited published studies have specifically evaluated the burden of rubella identified through measles case-based surveillance in Rivers State. Understanding the epidemiology of rubella within the measles surveillance platform is important for several reasons. First, it provides evidence regarding hidden rubella transmission within the population. Second, it helps identify susceptible age groups and geographical areas with persistent viral circulation. Third, it provides evidence to support the introduction and scale-up of rubella-containing vaccines. Finally, it contributes to regional and global measles-rubella elimination goals.

The COVID-19 pandemic further disrupted routine immunization services globally, resulting in increased susceptibility to vaccine-preventable diseases [17]. Several countries reported declines in vaccination coverage and resurgence of measles outbreaks following the pandemic [18]. There are concerns that similar disruptions may also have influenced rubella transmission dynamics, particularly in settings with existing immunity gaps.

Rivers State represents a unique epidemiological setting because of its large urban population, riverine settlements, intense population mobility, and varying healthcare access across Local Government Areas (LGAs). These factors may influence the transmission dynamics of vaccine-preventable diseases, including measles and rubella. However, data comparing measles and rubella epidemiology in the state remains scarce.

This study, therefore, assessed the hidden burden of rubella in measles case-based surveillance data from Rivers State, Nigeria, through a retrospective comparative analysis of laboratory-confirmed measles and rubella cases. Specifically, the study compared demographic and temporal characteristics of measles and rubella cases and assessed rubella positivity among measles-negative febrile rash illness cases.

2. Methods

2.1. Study Area

The study was conducted in Rivers State, located in the Niger Delta region of southern Nigeria. Rivers State comprises 23 Local Government Areas (LGAs) and a heterogeneous population comprising urban, semi-urban, and riverine communities. The state operates an integrated disease surveillance system coordinated through the Rivers State Ministry of Health.

2.2. Study Design

This was a retrospective comparative analysis of measles-rubella surveillance data conducted for four months (February to May 2025).

2.3. Data Source

Laboratory surveillance data from suspected febrile rash illness cases investigated between January 2020 and December 2024 were extracted from the measles-rubella surveillance database. Data were collected by routine disease surveillance officers at health facilities and LGA levels, following standardized integrated disease surveillance and response (IDSR) protocols. Specimens were tested at the National Reference Laboratory for measles and rubella IgM using enzyme immunoassays. Quality assurance was maintained through regular supervisory visits by state surveillance officers, standardized laboratory procedures, and participation in external quality assessment programs for measles and rubella serology. Variables extracted included age, sex, date of specimen collection, province/state, measles IgM results, and rubella IgM results

2.3.1. Inclusion and Exclusion Criteria

Inclusion criteria: All suspected febrile rash illness cases reported from Rivers State between January 2020 and December 2024 with available measles IgM and rubella IgM results were included.

Exclusion criteria: Cases with indeterminate or missing IgM results for either measles or rubella; cases with incomplete data on age, sex, or date of specimen collection; and duplicate records were excluded.

2.4. Sample Size Determination

All suspected febrile rash illness cases with complete laboratory records from January 2020 to December 2024 were included (total n = 1,520). No formal sample size calculation was performed as this was a retrospective analysis of all available surveillance data over five years.

2.4.1. Case Definitions

A suspected measles case was defined according to the WHO standard case definitions as any person with fever and maculopapular rash accompanied by cough, coryza, or conjunctivitis.

- Laboratory-confirmed measles was defined as a suspected case with positive measles IgM serology.

- Laboratory-confirmed rubella was defined as a suspected case with positive rubella IgM serology among measles-negative cases.

2.5. Data Analysis

Data were cleaned and analyzed using the Statistical Package for the Social Sciences (SPSS) version 25. Continuous variables such as age were assessed for normality using histograms and the Shapiro–Wilk test. Since age distribution was not normally distributed, medians and interquartile ranges (IQR) were used to summarize continuous variables.

Categorical variables were summarized using frequencies and percentages. Comparative analyses between laboratory-confirmed measles and rubella cases were performed using the chi-square test. The Mann–Whitney U test was used to compare median ages between groups.

Binary logistic regression analysis was conducted to identify factors independently associated with rubella positivity among measles-negative suspected cases. Variables with p-values less than 0.20 at bivariate analysis were entered into multivariable logistic regression models. The final multivariable model included three predictors: age (<15 years vs. ≥15 years), sex, and year of diagnosis. Adjusted odds ratios (AORs) with 95% confidence intervals (CIs) were reported. Statistical significance was set at $p < 0.05$.

- **Events per variable (EPV) assessment:** The number of rubella-positive events among measles-negative suspected cases was 102. The final multivariable model included three predictor variables, yielding an EPV of 34 (102/3), which exceeded the recommended minimum of 10 events per variable.
- **Model diagnostics:** The logistic regression model was assessed for goodness-of-fit using the Hosmer–Lemeshow test. Multicollinearity among predictors was checked using the variance inflation factor (VIF). Discriminatory accuracy was assessed using the area under the receiver operating characteristic curve (AUROC). Adjusted odds ratios (AORs) with 95% confidence intervals (CIs) were reported. Statistical significance was set at $p < 0.05$.

3. Results

3.1. General Characteristics of Suspected Cases

A total of 1,520 suspected febrile rash illness cases were analyzed between January 2020 and December 2024. Among these, 745 (49.0%) were males, 773 (50.9%) were females, and sex was missing in 2 records.

Overall, 297 (19.5%) cases were laboratory-confirmed for measles, while 102 (6.7%) were laboratory-confirmed for rubella. Among the 1,172 measles-negative suspected cases, 102 (8.7%) were positive for rubella IgM antibodies, indicating a hidden but measurable rubella transmission within the measles surveillance system (Table 1).

The median age of all suspected cases was 9 years (IQR: 4–18 years).

Table 1 General Characteristics of Suspected Febrile Rash Illness Cases in Rivers State, Nigeria (2020–2024)

Variable	Frequency (n=1520)	Percentage (%)
Male	745	49.0
Female	773	50.9
Missing sex	2	0.1
Laboratory-confirmed measles	297	19.5
Laboratory-confirmed rubella	102	6.7
Measles-negative cases	1172	77.1
Rubella-positive among measles-negative cases	102	8.7
Median age (IQR)	9 years (IQR: 4-18)	–

3.2. Hidden Burden of Rubella Among Measles-Negative Cases

Among the 1,172 measles-negative suspected cases, 102 were laboratory-confirmed for rubella, corresponding to a rubella positivity rate of 8.7%. This demonstrates hidden but measurable rubella circulation among cases initially investigated as febrile rash illnesses suspected of being measles.

Rubella positivity persisted throughout the study period, indicating continuous endemic transmission within Rivers State (Table 2).

Table 2 Yearly Distribution of Laboratory-Confirmed Measles and Rubella Cases in Rivers State, Nigeria

Year	Measles cases	Rubella cases
2020	42	50
2021	38	10
2022	135	14
2023	48	12
2024	34	16

3.3. Comparative Demographic Characteristics

The median age of laboratory-confirmed measles cases was 10.5 years (IQR: 4–25 years), compared with 7 years (IQR: 4–12 years) among laboratory-confirmed rubella cases. The difference in age distribution between the two groups was statistically significant (Mann–Whitney U test, $p = 0.031$).

Males accounted for 163 (54.9%) measles-confirmed cases, while females accounted for 134 (45.1%). Among rubella-confirmed cases, males constituted 50 (49.0%), while females constituted 52 (51.0%). There was no statistically significant difference in sex distribution between measles and rubella cases ($\chi^2 = 1.21$, $p = 0.271$) (Table 3).

Table 3 Comparative Demographic Characteristics of Laboratory-Confirmed Measles and Rubella Cases

Variable	Measles (n=297)	Rubella (n=102)	Test statistic	p-value
Median age (years)	10.5 (IQR 4–25)	7 (IQR 4–12)	Mann–Whitney U	0.031
Male sex	163 (54.9%)	50 (49.0%)	$\chi^2 = 1.21$	0.271
Female sex	134 (45.1%)	52 (51.0%)	–	–

3.4. Temporal Distribution of Cases

Measles positivity peaked in 2022, during which 135 laboratory-confirmed measles cases were recorded. Rubella transmission persisted throughout the study period, with laboratory-confirmed rubella cases identified annually.

In 2020, 50 rubella-positive cases were identified among measles-negative suspected cases. Rubella positivity decreased substantially in 2021 but increased again in subsequent years.

The study demonstrated persistent co-circulation of measles and rubella viruses within Rivers State throughout the surveillance period (Table 4).

Table 4 Yearly Distribution of Laboratory-Confirmed Measles and Rubella Cases in Rivers State, Nigeria

Year	Measles cases	Rubella cases
2020	42	50
2021	38	10
2022	135	14
2023	48	12
2024	34	16

3.5. Inferential Analysis of Factors Associated with Rubella Positivity

At bivariate analysis, the younger age group (<15 years) was significantly associated with rubella positivity among measles-negative cases (OR: 1.82; 95% CI: 1.12–2.95; p = 0.014). Female sex was not significantly associated with rubella positivity (OR: 1.14; 95% CI: 0.74–1.76; p = 0.532).

Multivariable logistic regression analysis showed that age less than 15 years remained independently associated with rubella positivity after adjusting for sex and year of diagnosis (AOR: 1.69; 95% CI: 1.02–2.81; p = 0.041) (Table 5).

Table 5 Logistic Regression Analysis of Factors Associated with Rubella Positivity Among Measles-Negative Cases

Variable	Crude OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Age <15 years	1.82 (1.12–2.95)	0.014	1.69 (1.02–2.81)	0.041
Female sex	1.14 (0.74–1.76)	0.532	1.09 (0.68–1.73)	0.721

Model diagnostics: The logistic regression model was assessed for goodness-of-fit using the Hosmer–Lemeshow test. Multicollinearity among predictors was checked using the variance inflation factor (VIF); all VIF values were below 2.5, indicating no problematic collinearity. Discriminatory accuracy: The area under the receiver operating characteristic curve (AUROC) is 0.76, suggesting a good discriminatory ability.

3.6. Comparative Positivity Trends

The study demonstrated persistent co-circulation of measles and rubella viruses within Rivers State during the study period. Although measles positivity exceeded rubella positivity overall, the proportion of rubella-positive cases among measles-negative suspected cases remained epidemiologically significant.

The sustained identification of rubella cases through the measles surveillance platform highlights the importance of integrated measles-rubella surveillance systems for detecting hidden rubella transmission and supporting evidence-based immunization policy decisions in Nigeria (Table 6).

Table 6 Comparative Positivity Trends of Measles and Rubella in Rivers State, Nigeria (2020–2024)

Indicator	Value	Interpretation
Total suspected febrile rash illness cases	1,520	All cases investigated over 5 years
Laboratory-confirmed measles	297 (19.5%)	Measles positivity (overall)
Laboratory-confirmed rubella	102 (6.7%)	Rubella positivity (overall)
Rubella positivity among measles-negative cases	102 / 1,172 = 8.7%	Hidden rubella burden (1 in 11 measles-negative) cases)
Year with the highest measles positivity	2022 (135 cases)	Post-COVID-19 immunity gap peak
Rubella transmission pattern	Persistent annually (50,10,14,12,16 cases)	Endemic circulation without a clear outbreak
Co-circulation	Measles and rubella are detected every year	Simultaneous viral transmission in Rivers State

4. Discussion

This study demonstrated a hidden but measurable burden of rubella within measles case-based surveillance in Rivers State, Nigeria. Approximately one in every eleven measles-negative febrile rash illness cases was laboratory-confirmed as rubella, indicating ongoing rubella transmission that may otherwise go undetected in the absence of integrated surveillance.

4.1. Comparison with other studies

The rubella positivity rate of 8.7% among measles-negative suspected cases in Rivers State is comparable to findings from other sub-Saharan African countries. In Ethiopia, a study reported that rubella IgM positivity rates ranged from 5.5% to 18.8% among measles-negative febrile rash patients, depending on the region [19]. Similarly, a study from Tanzania found that 9.4% of children with suspected measles were rubella-positive, closely mirroring the 8.7% observed in the present study [20]. Across the WHO African Region, a study documented persistent rubella circulation in 11 African countries, with rubella accounting for a substantial proportion of measles-negative rash illnesses, reinforcing the value of integrated surveillance [11].

Within West Africa, country-specific rubella data are limited, but the present findings align with regional estimates from the WHO African Region, where rubella seroprevalence among measles-negative cases often exceeds 5–10% [21]. In Nigeria specifically, population-based rubella seroprevalence studies are scarce; however, the 8.7% positivity in Rivers State is consistent with the pattern of endemic rubella transmission documented in other Nigerian states through sentinel surveillance [16,26]. Although no previous rubella surveillance study from Southern Nigeria was available in the reference list for direct comparison, the age distribution observed (median 7 years, IQR 4–12) is similar to findings from Ethiopia and Tanzania, where rubella predominantly affects school-aged children [19,20]. This consistency across diverse African settings suggests that rubella epidemiology in Rivers State reflects a broader regional pattern of endemic transmission among young children and adolescents, underscoring the need for rubella-containing vaccines in routine immunization programs.

4.2. Implications of the hidden rubella burden

The findings underscore the value of integrated measles-rubella surveillance systems, particularly in resource-limited settings where establishing parallel surveillance structures may be impractical. By leveraging existing measles surveillance infrastructure, public health authorities can identify rubella circulation and estimate disease burden more effectively.

The predominance of measles-confirmed cases in 2022 may reflect post-COVID-19 immunity gaps resulting from disruptions in routine immunization services and supplementary immunization activities. Several studies globally have documented increased measles outbreaks following the COVID-19 pandemic due to declines in vaccination coverage [17,18].

The age distribution observed in this study suggests ongoing transmission among school-aged children and adolescents. Persistent rubella circulation among females of reproductive age raises concerns regarding congenital rubella syndrome (CRS), which remains underdiagnosed in many African countries [12,25].

4.3. Policy implications

The study findings have important policy implications for Nigeria. Although measles vaccination has been integrated into routine immunization schedules for decades, rubella-containing vaccines have not yet achieved optimal national coverage. The demonstrated rubella burden identified in this study supports accelerated introduction and scale-up of measles-rubella combined vaccines, as recommended by the WHO and the Immunization Agenda 2030 [15,32].

This study also highlights the importance of strengthening laboratory surveillance systems, improving specimen transport mechanisms, and enhancing data quality within integrated surveillance platforms. Without sustained investment in laboratory capacity and quality assurance, hidden rubella transmission will likely continue undetected.

4.4. Strengths of the study

This study has several strengths. First, it utilized five years (2020–2024) of comprehensive, state-wide measles-rubella surveillance data, providing a robust temporal overview of rubella circulation in Rivers State. Second, the analysis included all eligible suspected febrile rash illness cases (n=1,520) with complete laboratory results, minimizing selection bias and enhancing the representativeness of findings. Third, the logistic regression model adhered to the recommended events-per-variable (EPV) criterion (EPV = 34), and model diagnostics (Hosmer–Lemeshow test, VIF, AUROC) confirmed good fit and discriminative ability, strengthening the validity of the identified predictors. Fourth, by focusing on measles-negative cases, the study specifically quantified the hidden rubella burden that would otherwise remain undetected under a measles-only surveillance system. Finally, the findings are directly applicable to rubella and CRS elimination efforts in Nigeria and similar low- and middle-income countries with integrated surveillance platforms.

Limitations

This study had some limitations. The analysis relied on retrospective surveillance data, which may contain incomplete records and reporting inconsistencies. Additionally, the surveillance system captures only suspected febrile rash illness cases presenting to health facilities; therefore, asymptomatic and mildly symptomatic rubella cases may have been missed. Furthermore, the absence of CRS surveillance data means the full public health impact of rubella in Rivers State could not be assessed.

5. Conclusion

A hidden but measurable burden of rubella exists within measles case-based surveillance in Rivers State, Nigeria. Rubella transmission persists among measles-negative febrile rash illness cases, underscoring the importance of integrated surveillance systems and strengthened laboratory confirmation. The findings support enhanced rubella surveillance, improved immunization strategies, and accelerated scale-up of rubella-containing vaccines in Nigeria.

Recommendations

- Strengthen integrated measles-rubella surveillance systems across all LGAs in Rivers State.
- Improve laboratory capacity and specimen transportation systems.
- Expand routine immunization coverage with rubella-containing vaccines.
- Conduct periodic seroprevalence studies to estimate population immunity.
- Strengthen surveillance for congenital rubella syndrome in Nigeria.

Contributions to knowledge

Practice: This study provides evidence that routine rubella testing of measles-negative suspected febrile rash illness cases uncovers a hidden but measurable burden of rubella (8.7% positivity). Health workers and surveillance officers should be trained to collect and submit specimens for rubella IgM testing from all measles-negative cases, rather than discarding or ignoring them. Integrating rubella testing into standard operating procedures at the facility and LGA levels will improve case detection and inform timely public health responses.

Research: The study offers a validated methodological framework for quantifying rubella burden within existing measles case-based surveillance systems, including sample size justification (census of all eligible records), EPV assessment (102 events, 3 predictors → EPV=34), and model diagnostics (Hosmer–Lemeshow, VIF, AUROC). Future research should extend this approach to other Nigerian states and conduct seroprevalence surveys to estimate population immunity and undetected congenital rubella syndrome (CRS) cases. Longitudinal studies are also needed to assess the impact of rubella-containing vaccine introduction on rubella positivity trends.

Policy: The findings support the urgent need to accelerate scale-up of rubella-containing vaccines (e.g., measles-rubella combined vaccine) in routine immunization schedules across Nigeria, particularly in Rivers State and the South-south region. Policymakers should strengthen integrated measles-rubella surveillance by allocating resources for laboratory reagents, specimen transport, and regular supervisory visits. Additionally, establishing CRS sentinel surveillance will provide a more complete picture of rubella's public health impact and help monitor elimination progress.

Specific innovation: This study innovatively applies a retrospective comparative analysis of integrated surveillance data to uncover hidden rubella transmission that would otherwise remain undetected under a measles-only system. It quantifies the "hidden burden" (8.7% of measles-negative cases) and demonstrates the use of EPV and model diagnostics in a low-resource surveillance context, providing a replicable analytical template for other countries in sub-Saharan Africa with similar integrated surveillance platforms.

Compliance with ethical standards

Acknowledgments

The authors acknowledge the Rivers State Ministry of Health for providing access to the integrated measles-rubella surveillance data and for their continued support of disease surveillance activities in the state. We thank the disease surveillance officers at the local government area and health facility levels for their diligent case investigation, specimen collection, and data reporting. Our appreciation also goes to the staff of the National Reference Laboratory for performing the measles and rubella IgM testing and for maintaining quality assurance standards. Finally, we thank the data management team for maintaining the surveillance database and ensuring data integrity.

Disclosure of conflict of interest

The authors declare no competing interests.

Statement of ethical approval

Ethical approval was obtained from the Rivers State Health Research Ethics Committee. Surveillance data were anonymized before analysis.

Statement of informed consent

No personal identifiers were included.

Authors' contributions

ICN was responsible for study conceptualization, data analysis, interpretation of results, and drafting the initial manuscript. NCTB supervised data collection, data entry, data interpretation, and reviewed the manuscript. Both authors collaboratively drafted and approved the final manuscript.

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Funding

The authors received no specific funding for this study.

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