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Research Article

Impact of Reactive Vaccination on the 2021 Meningitis Epidemic in Banalia (DRC)

Impact de la Vaccination Réactive sur l'Epidémie de Méningite de 2021 à Banalia (RDC)

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ABSTRACT

Introduction. The Banalia health zone reported a meningitis epidemic in 2021 that evolved outside the epidemic season. The aim of our study was to report challenges and best practices in implementing outbreak response interventions and assess their effects on the epidemiological evolution of the bacterial meningitis epidemic in Banalia. **Methods.** This cross-sectional study was retrospectively conducted from July to December 2021 in Banalia Health, which comprises 20 health areas with 171,001 inhabitants. The standard case definition was used to identify cases. Care was provided to 2,651 in-patients, with 8% of them laboratory tested, and reactive vaccination was conducted. The Wilcoxon–Mann–Whitney test was used to assess the relationship between cases that occurred before and after reactive vaccination. **Results.** Overall, 2,662 suspected cases of meningitis with 205 deaths were reported. Individuals aged 30–39 years were the most affected (38.5%). Case fatality rate decreased from 70.4% at the beginning of the epidemic to 7.7% . *Neisseria meningitidis* W was the predominant pathogen isolated, accounting 82% of the confirmed cases, of which 92% of the strains belonged to the clonal complex 11. Reactive vaccination of individuals in Banalia aged 1–19 years with a meningococcal multivalent conjugate (ACWY) vaccine (Menactra®) coverage of 104.6% resulted in an 82% decline in suspected meningitis cases (IRR= 0.18; 95% IC, 0.02–0.80; p = 0.041). **Conclusion.** Despite late detection and response to the meningitis epidemic in Banalia, reactive vaccination contributed to the control of the epidemic.

RESUME

Introduction. The Banalia health zone reported a meningitis epidemic in 2021 that evolved outside the epidemic season. The aim of our study was to report challenges and best practices in implementing outbreak response interventions and assess their effects on the epidemiological evolution of the bacterial meningitis epidemic in Banalia. **Methods.** This cross-sectional study was retrospectively conducted from July to December 2021 in Banalia Health, w hich comprises 20 health areas with 171,001 inhabitants. The standard case definition was used to identify cases. Care was provided to 2,651 in-patients, with 8% of them laboratory tested, and reactive vaccination was conducted. The Wilcoxon–Mann–Whitney test was used to assess the relationship between cases that occurred before and after reactive vaccination. **Results.** Overall, 2,662 suspected cases of meningitis with 205 deaths were reported. Individuals aged 30–39 years were the most affected (38.5%). Case fatality rate decreased from 70.4% at the beginning of the epidemic to 7.7% . Neisseria meningitidis W was the predominant pathogen isolated, accounting 82% of the confirmed cases, of which 92% of the strains belonged to the clonal complex 11. Reactive vaccination of individuals in Banalia aged 1–19 years with a meningococcal multivalent conjugate (ACWY) vaccine (Menactra®) coverage of 104.6% resulted in an 82% decline in suspected meningitis cases (IRR= 0.18; 95% IC, 0.02–0.80; p = 0.041). **Conclusion.** Despite late detection and response to the meningitis epidemic in Banalia, reactive vaccination contributed to the control of the epidemic.

HIGHLIGHTS

What is known of the subject

The Banalia health zone reported a meningitis epidemic in 2021 evolving outside the epidemic season. N. meningitidis W was identified as the cause by real-time polymerase chain reaction

The aim of our study

Impact of reactive vaccination on the 2021 meningitis epidemic in Banalia (DRC)

Key Results

1. Individuals aged 30–39 years most affected (38.5%).
2. Case fatality rate decreased from 70.4% at the beginning of the epidemic to 7.7% .
3. Reactive vaccination of individuals in Banalia aged 1–19 years with a meningococcal multivalent conjugate (ACWY) vaccine (Menactra®) coverage of 104.6% resulted in an 82% decline in suspected meningitis cases (IRR= 0.18; 95% IC, 0.02–0.80; p = 0.041).

Implications for future practices and policies

Allocating resources to reinforce laboratory capacity for quicker detection and confirmation of meningitis cases and applying the alert and epidemic thresholds as quickly as possible to guide a timely response.

INTRODUCTION

Bacterial meningitis is a major public health problem in the African meningitis belt, an area that stretches from Senegal in the west to Ethiopia in the east **[1-7].** Seasonal meningitis outbreaks occur annually in this part of the world mostly from epidemiological weeks (w) 1 to 26 (January–June **[8-9].** Despite significant progress in combating meningitis over the past 20 years, bacterial meningitis epidemics remain a significant global public health challenge, with over 1.2 million cases and 300,000 deaths occurring annually [**7].** The incidence and case fatality rates of bacterial meningitis vary by region, country, pathogen, and age group **[1].** In 2019, aproximately 2.5 million cases and 236,000 deaths due to meningitis were reported worldwide **[7,10].** Before 2010, *Neisseria meningitidis* (*N. meningitidis*) A was the leading cause of meningitis in the African meningitis belt, accounting for almost 90% of the epidemics **[7].** The introduction of meningitis A conjugate vaccine (MenAfriVac®) in the African meningitis belt since 2010 resulted in a significant reduction in the incidence of *N. meningitidis* A cases and a change in the bacterial profile of meningitis, with a predominance of *N. meningitidis* C, W, X, and *Streptococcus pneumoniae* (*S. pneumoniae*) **[8,10].** Since 2010, countries in the meningitis belt including Burkina Faso (BFA), Ghana, Nigeria, Niger, and Togo have reported meningitis epidemics caused by *N. meningitidis* C and W **[11-21].** The clonal complex (CC)11 has expanded throughout the meningitis belt **[18].** Although the detection and laboratory confirmation of pathogens causing meningitis epidemics is challenging in these countries, reactive vaccination is vital for controlling them. Documenting lessons learned from responses helps identify bottlenecks and best practices and improves the quality of preparedness, detection, and response over time **[11-20].** The Democratic Republic of Congo (DRC) is the African meningitis belt countries. In early July 2021, the Banalia health zone in the Tshopo province, located in the north-eastern DRC, notified several suspected cases and deaths due to meningitis through the alert system of the meningitis enhanced surveillance network of the African meningitis belt in which DRC was included. On September 6, 2021, *N. meningitidis* W was identified as the cause by real-time polymerase chain reaction (PCR) at the Institute Pasteur of Paris, France **[21,22, 25].** We report on the challenges and best practices in implementing outbreak response interventions to assess their effects on the epidemiological evolution of the bacterial meningitis epidemic in Banalia.

PATIENTS AND METHODS

Setting

This cross-sectional study was retrospectively conducted from July to December 2021 in Banalia Health, which comprises 20 health areas with 171,001 inhabitants. As the World Health Organization (WHO) recommends dividing areas with over 100,000 inhabitants into smaller intervention areas; two subhealth zones were identified, the left and right banks, with 88,311 and 82,690 inhabitants, respectively. Outbreak response interventions were implemented by the government with support from partners, including the WHO [**25-27].**

Meningitis surveillance

The DRC has the following two complementary meningitis surveillance systems: enhanced surveillance, which was introduced in 2003 in the six provinces in the meningitis belt (Bas Uele, Haut Uele, Ituri, Nord Kivu, Sud Kivu, and Tshopo), and pediatric bacterial meningitis sentinel surveillance, which was implemented in 2009 in three sites (Kinsasha, Lubumbashi, and Kisangani). The meningitis-enhanced surveillance aims to detect outbreaks. A suspected case of meningitis was defined by fever, neck stiffness, and one or more neurological signs **[28].** Enhanced and community-based surveillance were implemented by public health authorities during the epidemic, starting active case-finding on September 17 (w37), 2021 **[27, 28, 30].** As per WHO guidance, subhealth zones were classified as crossing the alert or epidemic thresholds when 3 or 10 suspected cases per 100,000 inhabitants per week were recorded, respectively **[27-30].**

Laboratory confirmation

Detection of bacterial pathogens is performed by culture or PCR in cerebrospinal fluid (CSF) specimens. A suspected meningitis case is defined as any person with sudden onset of fever (rectal, >38.5°C or axillary, 38.0°C) and neck stiffness or other meningeal signs, including bulging fontanel in infants. A probable case is defined as any suspected case with macroscopic aspect of turbid, cloudy, or purulent CSF; with a CSF leukocyte count of >10 cells/mm^3 or with bacteria identified by Gram staining in the CSF; or positive antigen detection in the CSF. In infants, a probable case is defined as a CSF leucocyte count of >100 cells/mm^3 or a CSF leucocyte count of 10–100 cells/mm^3 and either an elevated protein (>100 mg/dL) or decreased glucose (<40 mg/dL) level **[28].** To confirm the diagnosis, lumbar punctures were performed in the health facilities of Banalia on some suspected cases of meningitis. First-level laboratories in Kisangani performed Gram staining and latex agglutination (Pastorex®). Aliquots of all CSF specimens were shipped to the National Institute of Biomedical Research of Kinshasa for culture and PCR. On September 6, 2021, the Pasteur Institute of Paris (IPP) confirmed that *N. meningitidis* W was the main cause of the epidemic. A total of 213 isolates of CSF specimens were shipped to the IPP and the Centers for Disease Control and Prevention (CDC) of the United States for quality control and testing for antimicrobial resistance using the minimum inhibitory concentration method and molecular genotyping. Molecular typing was directly performed on CSF samples or cultured isolates by PCR amplification followed by sequencing of several genes to perform multi-locus sequence typing and fine typing (Proc Natl Acad Sci U S A 1998, 95, (6), 3140-5). Molecular antimicrobial testing was used for predicting susceptibility to beta lactams by penA sequence analysis as previously described (Antimicrob Agents Chemother 2007, 51, (8), 2784-92). Antimicrobial susceptibility testing was performed as recommended by the European Monitoring Group on Meningococci (Vazquez et al. Antimicrob Agents Chemother 2003, 47, (11), 3430-4). Ebola virus disease and any heavy metal poisoning were excluded through biological and biochemical laboratory tests. Eight hundred suspected meningitis cases benefited from latex agglutination rapid diagnostic testing for malaria. One patient with respiratory symptoms was tested for coronavirus disease 2019 (COVID-19) using a rapid diagnostic test, and PCR was not performed for confirmation.

Infection prevention and control (IPC)

IPC activities were performed from w31 to w50 in 2021. The aim was to prevent COVID-19 and meningitis transmission in health facilities. IPC encompassed cleaning and disinfection of latrines and meningitis treatment centers, chlorination of handwashing points, and promotion of wearing mask in Banalia public areas and health facilities.

Public health response

The national health authorities provided support in responding to this outbreak in coordination with the WHO, United Nations Children's Fund, Gavi, The Vaccine Alliance, International Coordinating Group (ICG) on Vaccine Provision, CDC of the United States, Doctors Without Borders (MSF), World Bank, and civil society. The response measures included the deployment of national and provincial rapid response teams that conducted investigations and organized response structures and mobile clinics to ensure appropriate case management with ceftriaxone administration, sample collection, and IPC measures to prevent COVID-19 comorbidity in the affected areas. To determine the epidemiological linkage, in-depth investigations at the community level were conducted. Alerts and active searches for contacts were established through community-based surveillance in the mining quarries and community. The meningitis epidemic in Banalia was detected on July 3 during epidemiological w21 of 2021. On September 6, 2021, *N. meningitidis* W was confirmed as the predominant cause, and the government officially declared the epidemic on September 7, 2021 (w35). This epidemic had the particularity of evolving after the meningitis epidemic season (w1–26), and the last case was notified on December 20 (w49). A request for vaccine doses was submitted to the ICG, which approved the release of doses of the multivalent conjugate ACWY meningococcal vaccine (Menactra®). Menactra® vaccine doses were delivered to the DRC on October 1, 2021, and the reactive vaccination campaign was conducted from October 9 to 16, 2021 to 162,518 inividuals in Banalia aged 1–49 years. Regarding case management, ampicillin and gentamicin were administered to patients before w31, and ceftriaxone replaced these antibiotics. Furthermore, syndromic treatment was administered. The psychological management of patients and health workers was performed in the Panga Health facility by a psychologist to patients and health workers living in Banalia. Over 50% of the individuals assisted were living in Panga, and 5,442 people, patients, and health workers were screened and sensitized on the risk of depression. Among them, 771 patients and 321 health workers received psychological support. Patients who were victims of another traumatic event (mourning of a loved one or having a serious illness) after recovery from meningitis were excluded from the study. To screen for depression, the HAD scale by Zigmond and Snaith was administered more than 1 month following meningitis management. Any case whose HAD score was over 10 was considered a case of depression. Risk communication activities were implemented. The local, provincial, and national coordination committees of health emergencies conduct regular meetings **[27, 33, 34].**

Data collection and statistical analysis

From January to December 2021, data were retrospectively collected from health facility registers and reported in a line list. The incidence rates of suspected meningitis cases were calculated for each epidemiologic week of the two subhealth zones. To guide public health response, rates at both health and subhealth zone levels were compared with WHO-established thresholds **[15, 16].** Vaccine administrative coverage was estimated using the number of vaccinated individuals and the target population of 146,990 1–49-year-old individuals. Laboratory data were included in the analysis. Only 2,444 of 2,662 meningitis suspected cases were used for statistical analyses owing to missing data. All 213 (100%) CSF specimens were adequate. They were analyzed either by PCR (n = 114) or culture (n = 102), and 112 CSF samples were tested using both methods. To determine differences between the distribution of suspected cases among age groups, gender, and status of alive and dead, the Kruskal–Wallis rank sum test was employed. The Wilcoxon–Mann–Whitney test was used to assess the relationship between the number of cases that occurred before and after reactive vaccination, and the incidence rate ratio (IRR) was determined to be the correlation between the number of deaths that occurred before and after the introduction of ceftriaxone. The confidence interval used was 95% with a significance level of <0.05.

Ethics considerations

During the study, respect for human beings was followed. The anonymity and confidentiality of patients were respected. Research and publication authorization from the Ministry of Health were approved.

RESULTS

Outbreak detection, investigation, and spread

The meningitis epidemic in Banalia was detected during the 26th epidemiological week (w) of 2021 at the beginning of July and officially declared late on September 7, 2021 (w35). The first cases were recorded in the Panga Health area located 277 km north of Kisangani and in the Wabelo and Rapid intervention mine quarries 4 km upstream and 6 km downstream of the Panga Health facility, respectively. From this health area, the epidemic spread to the nineteen other health areas in the Banalia health zone. The right bank subhealth zone crossed the epidemic threshold in w21 (11.7/100,000 inhabitants), whereas the left bank subhealth zone in w25 (10/100,000 inhabitants). The right bank subhealth zone was the most affected, with a cumulative attack rate of 3,327 cases/100,000 population with 107 deaths and a 9.2% lethality rate (Table I). This epidemic was unusual in that it evolved after the meningitis epidemic season (w1–26). The end of the epidemic was officially declared in w50 (December 23, 2022), and the peak was reached in w40 and lasted for 31 weeks, which was almost 7 months **(Table I).** At w44, 2,449 suspected and 213 confirmed meningitis cases with 205 deaths had been recorded, with a CFR of 7.7%.

Table I. Characteristics of the meningitis epidemic in right bank and left bank sub-health zones, Tshopo, Banalia, Democratic Republic of Congo from 7 June to 27 November 2021

Sub-health zones	Population	Cumulative Suspected Cases	Cumulative Attack Rate (per 100 000 Inhabitants)	Weeks in Which Epidemic Threshold Was Crossed (Number of Suspected Cases)	Cumulative Deaths	Case Fatality Ratio (%)
Right bank	79,319	1,844	2,326.1	w21 (13),w22 (8),w24 (10),w25 (20),w26 (16),w27 (18), w28 (17),w30 (14),w31 (10),w33 (13),w34 (34),w35 (25), w36 (61),w37 (217),w38 (223),w39 (258),w40 (312),w41 (253),w42 (125),w43 (108),w44 (56)	170/2,326.1	9.2
Left bank	88,286	818	926.5	w35 (14), w36 (32), w37 (81), w38 (136), w39 (150), w40 (116), w41 (118), w42 (90), w43 (26), w44 (17)	35/926.5	4.3
Banalia health zone	167,605	2,662	1,588.9	W 21-44	205/2,662	7.7

w: epidemiological week

The number of meningitis suspected cases reported was the highest among individuals aged 30–39 years (927/2,409 [38.5%]), followed by those aged 15–29 years (647/2,409 [26%]), ≥50 years (396/2,409 [16%]), 5–14 years (251/2,409 [10%]), and 0–59 months (188/2,409 [7.7%]) ($p < 0.001$); of the 2,662 suspected cases, 253 (9.5%) had missing data. Males and females represented 1,280/2,447 (52.5%) and 1,163/2,447 (47.5%) suspected cases, respectively. However, no statistical difference was observed between males and females ($p = 0.8$). A total of 2,457/2,662 (92.3%) suspected cases were treated, and 205 cases died. The proportion of alive individuals was higher than that of deaths with statistical difference ($p < 0.001$) **(Table II).**

Laboratory confirmation

Of 2,662 suspected cases, 213 (8%) CSF specimens were collected and tested. Of the 213 specimens, 57 (26.7%) were positive for bacterial meningitis pathogens by at least one confirmation method. Of the 57 specimens with positive confirmatory test results, 47 (82%), 4 (7%), 3 (5%), 2 (3%), and 1 (2%) were identified as *N. meningitidis* W, *N. meningitidis* C, *S. pneumoniae*, *Hemophilus influenzae b*, and *Hemophilus influenzae non-b*, respectively (**Table III).** The molecular genotyping performed by IPP showed a W genome: P1.5.2. F1-1: clonal complex CC11 (92%), and the strains belonged to the Anglo–French–Hajj lineage. One suspected meningitis case that tested positive for COVID-19 using a rapid diagnostic test died. In contrast, 800/2,662 (30%) suspected meningitis cases were tested using a rapid diagnostic test for malaria, and 77/800 (9.6%) were positive.

Case management and reactive immunization

From June 7 to August 4, 2921, the treatment protocol included ampicillin and gentamycin with a cumulative CFR of 70.4%.

Table II. Distribution of age groups, sex, alive and deaths in Banalia health zone

Variables	Meningitis suspected cases (n^2/N^3)	p-value
Age group (year)		
0-4	188/2,409 (7.8%)	
5-14	251/2,409 (10.5%)	
15-29	647/2,409 (26.8%)	<0.001*
30-49	927/2,409 (38.5%)	
50 and above	396/2,409 (14.4%)	
Missing data	253/2,662 (9.5%)	
Gender		
Female	1,163/2,447 (47.6%)	0.8**
Male	1,284/2,447 (52.4%)	
Missing data	215/2,662 (8%)	
Status		
Alive	2,457/2,662 (96.3%)	<0.001*
Death	205/2,662 (7.7%)	

n^2: number case N^3: total number; * Kruskal-Walli's rank sum test** Wilcoxon rank sum test

Subsequently, on August 5, 2021, ceftriaxone was introduced, replacing ampicillin and gentamicin, and the cumulative CFR decreased to 7.7% at the end of the epidemic, with 205 deaths of 2,662 suspected cases **(Figure 1).** Reactive vaccination was conducted from October 9 to 16, 2021, and 153,88 of 146,990 target individuals aged 1–49 years were vaccinated, with a coverage rate of 104.6% **(Figure 2).**

Table III. Meningitis pathogens isloted confirmed during the meningitis epidemic in Banalia health zone

Pathogens confirmed	Meningitis pathogens n^1/N^2 (%)
N. Meningitidis W	47/57 (82.5%)
N. Meningitidis C	4/57 (7%)
S. pneumoniae	3/57 (5%)
Haemophilus influenzae b	2/57(3,5%)
Haemophilus influenzae non-b	1/57 (2%)
Total	57/57 (100%)

n^1: Number of pathogens positive, N^2 : 57 CSF collected and tested positive

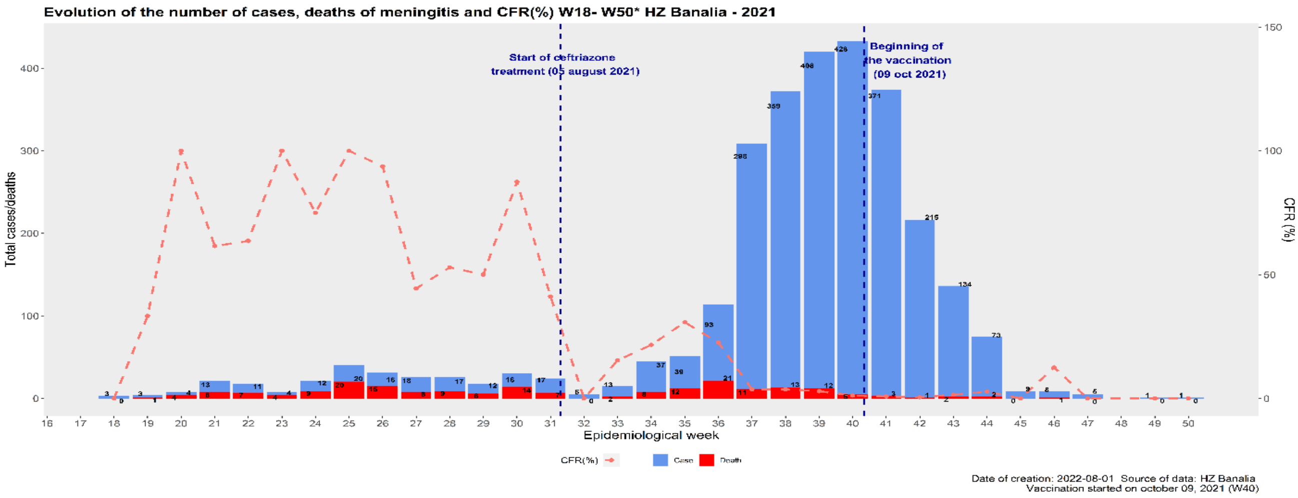

Figure 1. Evolution of meningitis suspected cases, deaths, and case fatality rates in Banalia, Democratic Republic of Congo from June 7 to November 27, 2021

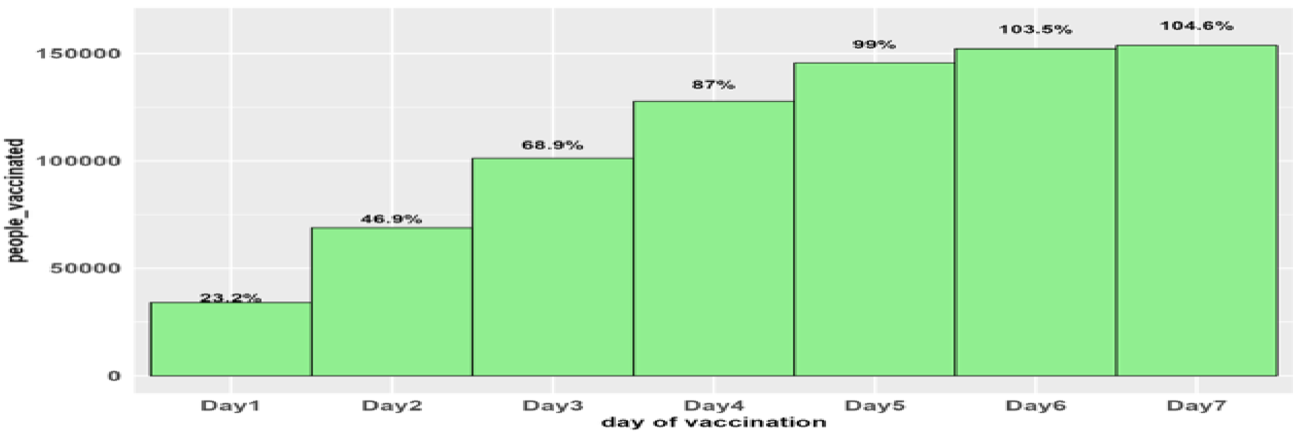

Figure 2. Daily evolution of Menactra® vaccination coverage in Banalia, Democratic Republic of Congo from October 9 to 16, 2021

Statistical analysis showed a high degree of correlation between the reactive vaccination campaign with Menactra® and the occurrence of cases (p = 0.001) **(Table IV).**

Table IV. Relationship between the number of cases and deaths before and after reactive vaccination and ceftriaxone introduction

Variable	Number of cases		p-value
	Before reactive vaccination (w* 21–40)	After reactive vaccination w 41–47	
Cases and deaths before and after interventions	1745	908	0.001

w: epidemiological week, [1]Wilcoxon rank sum test

This study showed that after reactive vaccination, an 82% decline in the number of meningitis suspected cases was observed, which contributed to ending the epidemic (IRR, 0.18; 95% CI, 0.02–0.80; p = 0.041) **(Table V).**

Table V. Correlation between meningitis incidence before and after reactive vaccination and number of related deaths before and after ceftriaxone introduction in the treatment protocol

Variables	IRR[1]	95% CI[2]	p-value
Reactive vaccination campaign			
Before (suspected cases)	—	—	
After (suspected cases)	0.18	0.02, 0.80	0.041

[1]IRR = Incidence Rate Ratio, [2]CI = Confidence Interval

A negative correlation was observed between ceftriaxone administration and CFR (p = 0.013; incidence rate ratio [IRR] 12.5, 95% CI 1.48–114). Following reactive vaccination, there was an 82% decline in the number of suspected meningitis cases, which contributed to ending the epidemic (IRR 0.18, 95% CI 0.02–0.80, p = 0.041)

DISCUSSION

With 2,662 suspected cases and 205 deaths, the Banalia meningitis epidemic is one of the largest epidemics caused by *N. meningitidis* W reported in the meningitis belt countries in the last decade. Other countries that declared large epidemics of *N. meningitidis* W included BFA, Niger, and Togo **[12, 14, 15].** The WHO recommends early detection of meningitis epidemics [28-30]. However, the alert and epidemic thresholds were not applied at the beginning of the epidemic. This explains why this epidemic was detected 5 weeks later when the right bank subhealth zone had already crossed the epidemic threshold. From w21 to w30, the CFR was very high at 70.4%, probably because of ampicillin and gentamycin administration, which are not recommended by the WHO. When ceftriaxone was introduced, the CFR markedly decreased from 70.4% to 7.7% in w47. A CFR of ≥10% is considered high [28]. Furthermore, Togo and BFA reported a CFR of 10% [**12, 13, 17].** The age group most affected by meningococcal meningitis is typically the 1–29-year-old age group [30]. In Banalia, meningitis incidence was very high among adults, such as in Togo in 2016 **[12],** whereas children were the most affected in Niger and BFA **[14, 15].** Males (1,280/2,447 [52.4%]) were more affected than females (1,163/2,447 [47.6%]). This result is similar to epidemics reported in BFA, Niger, and Togo **[12, 14, 15, 35].** Regarding case management, the definition of a suspected meningitis case, which was the one recommended by the WHO, allowed the correct identification of patients for treatment **[28].** At the start of the alert phase, a combination of ampicillin and gentamicin was used for treatment, which was inappropriate because the WHO recommends ceftriaxone **[28, 30].** The chemoprophylaxis regimen deviated from the WHO recommendations [28, 30]. Health authorities of the Ministry of Health disagreed and justified that it was to avoid antimicrobial resistance to ciprofloxacin. Expectedly, based on experiences from other countries including BFA, Togo, Niger, and Benin, ceftriaxone administration markedly decreased the CFR [**12, 13, 17, 18].** Health authorities ensured that after care was in place, offering psychological support to patients and health workers. Finally, to reduce the risk of comorbidity (e.g., COVID-19) and further transmission of meningitis within the healthcare setting, IPC activities were implemented **[19-21].** The number of CSF specimens collected (8%) was very low, and at least 50% should be collected [28]. Despite the low confirmation rate, we identified CC11 as the main cause of this epidemic circulating in the African meningitis belt over the last 20 years [**12, 13, 17,18].** The strains belong to the Anglo–French–Hajj lineage, which has occurred in different sublineages across Africa [**18].**
Reactive vaccination seems to have contributed to the dramatic decline in cases, as shown in other countries (BFA, Niger, Benin, and Brazil) [**12, 14, 15, 33].** However, the campaign, which started in w40, was very late, almost 20 weeks after the start of the epidemic. WHO recommends vaccination within 4 weeks following meningitis epidemic detection **[18,20].** Unfortunately, delays in initiating reactive vaccination frequently occur in countries. Recent reactive campaigns in BFA, Niger, and Togo have also reported delays **[12, 13, 17].** However, in all these cases, vaccination was initiated <12 weeks following epidemic detection. Coordination was initially weak and scaled up progressively following the official declaration of the epidemic **[19-21].** Partners contributed to strengthen the epidemic response. The afteraction review supported by the WHO contributed to evaluating preparedness and response to the epidemic and identified as lessons learned the need for earlier detection and faster reactive vaccination [**19-21].** This study had some limitations. First, 253/2,662 (9.5%) and 215/2,662 (8%) missing data on age and gender, respectively, were observed. Therefore, to estimate the proportions of age and gender, 2,409 and 2,447 were designated as the denominator, respectively. This situation can be explained by the poor quality of data reporting in case investigation forms in a few health facilities in Banalia. Second, the proportion of CSF specimens tested was very low (213/2,662 [8%] cases) because of a lack of lumbar puncture kits and only

few health workers capable of performing lumbar puncture. The WHO recommends at least 50% of CSF collection among meningitis suspected cases **[28].**

CONCLUSION

despite the late detection of the bacterial meningitis outbreak in Banalia, adequate case management including the best practice of setting up psychosocial aftercare and conducting a reactive vaccination campaign made it possible to reduce lethality, stop the epidemic, and reduce its negative effects on the affected population. We recommend allocating resources to reinforce laboratory capacity for quicker detection and confirmation of meningitis cases and applying the alert and epidemic thresholds as quickly as possible to guide a timely response.

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Competing interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

Authors' contributions

All the authors contributed to design and development of the study project (2) TCBB: acquisition of data, analysis and interpretation of results (3) TCBB, JE: writing of the article, critical revision intellectual content (4) DDA: final approval of the version to be submitted.

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