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FOREWORD

In this issue:

Odyssean malaria is an unusual but recurrent occurrence in South Africa, especially in Gauteng Province. It refers to locally acquired malaria in one or more persons who have no recent travel history to an endemic area, implying that infective mosquitoes are occasionally transported to non-endemic areas – most likely by road transport – where they subsequently bite and infect one or more local residents. This issue describes two linked odyssean malaria cases that occurred in Kempton Park, Ekurhuleni District, in October 2021, once again reminding healthcare personnel to test for malaria in patients with unexplained febrile illness, even if they have not visited a malaria-affected area recently.

The World Health Organization urges all countries to prioritize antimicrobial resistance surveillance for selected organisms including carbapenem-resistant Enterobacterales (CRE). This issue contains the 2019-2020 CRE surveillance report from four sentinel sites in Gauteng Province, South Africa, during which an alarming 86% of the samples received tested positive for genes that facilitate resistance mechanisms in carbapenemase-producing Enterobacterales. This report also highlights sub-optimal functioning of the surveillance system at these sites and gives recommendations for their improvement.

Also in this issue is the acute flaccid paralysis (AFP) surveillance report for 2020. This surveillance system is used to monitor the possibility of circulating poliovirus. No wild-type nor vaccine-derived poliovirus were detected in South Africa during the surveillance period. Sabin poliovirus type 2 and circulating vaccine-derived poliovirus type 2 (cVDPV2) were however detected from 13 other African countries, highlighting the importance of ongoing surveillance and the need for logistical improvements to the surveillance system.

All contributors are thanked for their inputs, and we trust you will find these reports useful and interesting.

Basil Brooke, Editor

ODYSSEAN MALARIA IN KEMPTON PARK, GAUTENG PROVINCE – SEPTEMBER 2021

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Summary

Locally-acquired malaria is generally limited to endemic areas but local cases can occur outside of these areas owing to the inadvertent transfer of infective mosquitoes by means of road or air transport, referred to as 'odyssean malaria'. Typically, delayed diagnosis and treatment leads to severe malaria illness and sometimes fatal outcomes. Two suspected odyssean malaria cases from the same residence in Kempton Park were investigated. Neither had a history of travel to a malaria endemic region. A site inspection by a multi-sectoral team led by NICD staff revealed no obvious malaria threat in the vicinity of the index house or at other relatives' houses that the patients frequently visited. Genotyping of the parasites in the patients' residual blood smears revealed the same strain of *Plasmodium falciparum*. Both patients required intensive care for severe malaria, but recovered on appropriate treatment. Health facilities in the vicinity were advised to maintain a high index of suspicion for malaria in febrile patients with unexplained illness, even in the absence of a travel history to a malaria-endemic area.

Introduction

Malaria (a category 1 notifiable disease) is a preventable and curable disease caused by *Plasmodium* species, which can be fatal if not timeously diagnosed and treated. The vectors are certain *Anopheles* mosquito species that prefer warm and humid climatic conditions. In southern Africa's endemic areas malaria is seasonal with the rates of transmission highest during the summer months (September to May).

Malaria transmission in South Africa is generally confined to areas of the lowveld, especially those bordering Mozambique, Botswana and Zimbabwe. The most affected districts occur in northern KwaZulu-Natal, Limpopo and Mpumalanga provinces, which are endemic for malaria. There is, however, an additional risk outside these endemic areas due to the capability of infected mosquitoes to travel by means of air, road, rail or sea transport.

These hitch-hiking mosquitos are capable of infecting more than one person on route or at their destination - referred to as 'odyssean malaria'.[1] Odyssean malaria is uncommon and so delayed diagnosis and treatment can lead to complications with severe, sometimes fatal outcomes.[1]

Gauteng Province is not endemic for malaria and therefore its disease burden largely derives from residents travelling to and from endemic areas/countries (imported malaria), and from occasional odyssean malaria incidents. Gauteng's importance as a transport hub, including OR Tambo International Airport, which is utilised by a great many travellers, raises the risk and incidence of imported and odyssean malaria.[1]

On Wednesday 29th October 2021, the Ekurhuleni District Health office notified the National Institute for Communicable Diseases (NICD) of two suspected odyssean malaria cases in Kempton Park. These cases did not have a recent travel history outside Gauteng Province or the country, and resided at the same address. There was therefore a high index of suspicion of odyssean malaria. An outbreak response team was activated, comprising four staff from NICD (a pathologist, an entomologist, two public health registrars) and five Ekurhuleni District Health office personnel, comprising environmental health practitioners and outbreak response team members.

The aim of the outbreak response team was to confirm the diagnoses of odyssean malaria, collect patient samples for parasite genotyping and investigate the cases' residence and other places of interest for the presence of mosquito vectors, and to identify any situational risk factors that could be linked to malaria. The team therefore visited the residence of the cases (Figure 1, mapped as B), a residence of their family where they frequently overnight (mapped as C) and that of another family that they frequently visit (mapped as A).

Case & environmental investigation report

Kempton Park is a suburb within the Ekurhuleni Municipality with a total population of 171 575 and a population density of 1151 persons/km^2.[2] The municipality includes OR Tambo International Airport, many industry headquarters and logistics companies and major industrial sites, a power station and entertainment facilities. The odyssean cases reported from there are described below and in Table 1.

Table 1. Summary of odyssean malaria cases reported by Arwyp Medical Centre, Kempton Park, Ekurhuleni District, Gauteng Province, South Africa.

Patient (sex, age)	Date of onset of symptoms	Symptoms	Date diagnosed (notified)	Treatment	Status	Comment
Female, 24y	24/09/2021	Myalgia, headache, fatigue, chills	29/09/2021 (29/09/2021)	Artesunate, Coartem	Recovered and discharged	Severe disease with ICU admission and mechanical ventilation.
Male, 25y	27/09/2021	Diarrhoea, vomiting, myalgia, headache	30/09/2021 (30/09/2021)	Artesunate, Coartem	Prolonged hospitalisation, but discharged for home recovery	Severe disease with ICU admission and mechanical ventilation, complicated by acute respiratory distress syndrome and superimposed bacterial infection. Required renal dialysis for acute kidney Injury.

Case A: Case-patient A (24 y/o) symptom onset was Friday 24 September 2021. Her symptom profile included myalgia, headaches, fatigue and chills. Over the course of the weekend her symptoms did not improve and she initially visited a medical practice on Monday 27 September. COVID-19 was part of the differential diagnosis and with no relevant travel history, she was discharged with a negative COVID-19 PCR and home-based treatment. On 29 September, her condition worsened and she was rushed to the nearest medical facility. Here she was admitted to ICU, with her initial blood work showing thrombocytopenia and thereafter *Plasmodium falciparum* parasites were confirmed. Due to the absence of a travel history, odyssean malaria was suspected. She completed a full course of antimalarial treatment with intravenous artesunate, followed by oral artemether-lumefantrine (Coartem). During her admission she also developed bloodstream infections with *Staphylococcus capitis* and *Candida parapsilosis.* These resolved and her condition stabilised and improved. She was successfully discharged from hospital and recovered at home.

Case B: Case-patient B (25 y/o), husband of case-patient A, developed symptoms on 27 September. He experienced diarrhoea, vomiting, myalgia and headaches. At this stage, he visited a medical practice, where

he received symptomatic treatment. He also did not have any relevant travel history and had a negative COVID-19 PCR. His symptoms worsened, with dehydration, and he was rushed to the same medical facility on 30th September for emergency admission to ICU. Shortly thereafter he was intubated and ventilated. Due to the confirmation of the malaria diagnosis on his wife, his primary blood work-up included a formal malaria smear. He had a thrombocytopenia as well as acute kidney injury. His malaria smear was positive for *P. falciparum*. He required regular dialysis as well as mechanical ventilation. At one point in time he had to be reintubated due to complications of acute respiratory distress syndrome. After an additional period of mechanical ventilation and tailored treatment, he recovered and was successfully extubated. He completed the full antimalarial course of artesunate IV followed by artemether-lumefantrine (Coartem) orally. He was discharged to recover at home, where he required additional nutritional support, renal care and blood transfusion.

Because both infections occurred almost simultaneously in a married couple, the incubation period and time of onset of disease indicated several potential sites where they could have been infected (Figure 1), and these were investigated.

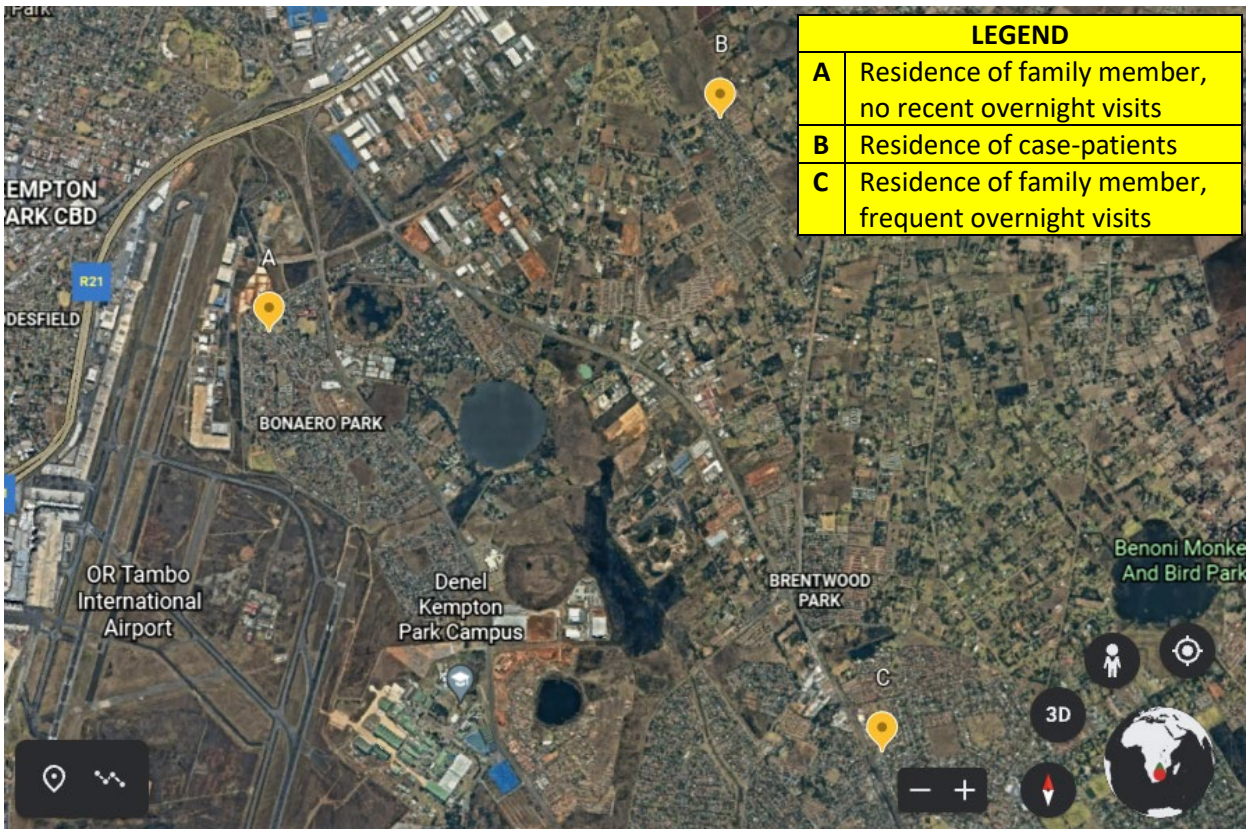

Figure 1. Satellite image showing locations of the residences investigated, Kempton Park, Ekurhuleni Municipality, Gauteng Province, South Africa.

Entomological investigations: No *Anopheles* mosquito adults or larvae were detected indoors or on the properties of A, B and C or their surrounds.

Parasite specimens: Residual laboratory blood specimens of both patients were acquired, and were PCR positive for *P. falciparum*. Genotyping at the NICD's Parasitology Reference Laboratory was conducted and it was concluded that the infections were caused by the same parasite strain, and therefore a single mosquito was responsible for transmission in both cases.

Discussion & conclusions

Based on the date of onset of symptoms in the case-patients, the most likely scenario is that they were bitten and infected during the night in the same house, which occurred either at residence B or C. Based on a parasite incubation and development period of 7 to 14 days, these infections would have occurred during early to mid-September 2021. As neither patient reported travel to a malaria-affected region during that period, both cases are classified as odyssean malaria.

Situational analyses revealed no major transport hubs in close proximity (within 1.5 km based on maximum mosquito dispersal distance) to any of the residences investigated. There were additionally no industries in close proximity to any of the residences, and no apparent travel by any close neighbours to a malaria affected area, as far as could be ascertained. No mosquito breeding sites could be identified and no adult mosquitoes were found in any of the dwellings.

It is therefore concluded that the patients were most likely infected by the same infective *Anopheles* mosquito during the same night or within a few days of each other, and that the culprit mosquito was inadvertently transported from a malarious area by road transport (car, taxi, bus etc). The mosquito would have exited the vehicle in close proximity to either residence B or C, thereafter seeking blood meals and transmitting malaria infections during that process.

Recommendations

As there were no follow-on cases, no vector control measures were required. It was, however, recommended that health facilities in the vicinity maintain a high index of suspicion for malaria in febrile patients with unexplained illness, even in the absence of a travel history to a malaria endemic area. It was also recommended that health promotion activities include malaria symptom awareness and the need to seek prompt medical assistance should these symptoms develop.

The current malaria guidelines, alerts and frequently asked questions are available on the NICD website (www.nicd.ac.za).

Acknowledgements

The Ekurhuleni District Team are thanked for their support and participation during this investigation. Prof Lucille Blumberg (NICD), Dr Mariana Khoza (University of Witwatersrand), Theodora Moloto, Christina Mnisi, Gladys Molefe (Ekurhuleni District Team and Environmental Health Practitioners) are thanked for their guidance and advice.

References

1. Frean J, Brooke B, Thomas J, Blumberg L. Odyssean malaria outbreaks in Gauteng Province, South Africa, 2007 - 2013. *S Afr Med J*. 2014;104(5):335-8.
2. Info SA [Internet]. Kempton Park. South Africa: Info SA; [updated 2021; cited 2021 Oct 20]. Available from: https://www.infosa.co.za/provinces/gauteng/gauteng-towns-cities/kempton-park/

SURVEILLANCE FOR BLOODSTREAM INFECTIONS CAUSED BY CARBAPENEM-RESISTANT ENTEROBACTERALES IN SOUTH AFRICA, 2019 AND 2020

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Summary

The World Health Organization has recently urged all countries to prioritize antimicrobial resistance surveillance for selected organisms including carbapenem-resistant Enterobacterales (CRE). We conducted a mixed-methods cross-sectional study with both quantitative and qualitative components using GERMS-SA enhanced CRE national surveillance at four sentinel sites in Gauteng Province (Steve Biko academic, Charlotte Maxeke Johannesburg Academic Hospital, Chris Hani Baragwanath, and Dr. George Mukhari), South Africa, from 1 January 2019 to 31 December 2020. A case was defined as any person from whom Enterobacterales was isolated from blood culture and was resistant to ertapenem or any other carbapenem if ertapenem susceptibility testing was not done (doripenem, imipenem, meropenem).

Laboratory-based surveillance for CRE from bloodstream infections was performed at the National Institute for Communicable Diseases (Centre for Healthcare-Associated Infections, Antimicrobial Resistance and Mycoses (CHARM), South Africa. Sentinel laboratories submitted case report forms together with isolates to CHARM for phenotypic and genotypic characterization, as well as antimicrobial susceptibility testing. A surveillance audit comprising demographic and laboratory characteristics was conducted using data extracted from the National Institute for Communicable Diseases surveillance data warehouse. CRE bloodstream infection cases were described epidemiologically and surveillance attributes pertaining to simplicity, acceptability, usefulness, and timeliness were evaluated. Qualitative data were

collected through a Google Forms online survey, distributed to participants by email. During this surveillance evaluation, a total of 1 266 case-patients was detected from the four enhanced sentinel sites. The median age of the cases was 35 years (Interquartile range (IQR), 17–52 years) and males accounted for 53% (n=673). Among CRE case patients, outcomes were known for 64% (n=810) and 38% (310/810) were known to have died. Of the total cases, 43% (n=556/1 265) were audit (only demographic and laboratory data, no isolates sent to CHARM). CHARM received 709 isolates from the sentinel laboratories. Of those, 86% (609/709) were viable and tested positive for genes present in carbapenemase-producing Enterobacterales. Online questionnaires were distributed to forty surveillance system stakeholders, of which 65% (n=26) consented to participate. Ninety-two percent (22/24) of participants reported that the role they played in this CRE surveillance system was their responsibility and 63% (15/24) of those reported that their roles did not require a lot of effort. The system evaluation reported longer durations between the steps of the surveillance system; the median time taken from CRE diagnosis to receipt of specimen at the surveillance laboratory was 9 days (IQR 5–14 days), and the median time from when isolates were received by the surveillance laboratory to phenotypic characterization was 15 days (IQR 7–53 days). About 76% (19/25) were not aware of the purpose of the data collected by the CRE surveillance system and 50% (13/26) reported never receiving any feedback on data collected by the surveillance system. The sub-optimal survey response rate and participants not knowing about surveillance reports suggest that the GERMS—SA surveillance system was not operating as effectively. To improve usefulness, the GERMS-SA CRE surveillance implementers should facilitate ongoing training and non-electronic dissemination of surveillance findings to stakeholders.

Background

Enterobacterales are a large group of Gram-negative bacteria that are found in humans, animals, and the environment. These include the highly adaptable *Escherichia coli, Serratia* spp*, Klebsiella pneumoniae* spp, and *Enterobacter* spp.[1] Enterobacterales have developed resistance to various antibiotics including the carbapenems.[1] Carbapenems are a class of broad-spectrum beta-lactam antibiotics that include imipenem, meropenem, ertapenem, and doripenem.[2] In the treatment of multidrug-resistant bacterial infections, carbapenems are considered the last line of antimicrobials.[2]

Carbapenem-resistant Enterobacterales (CRE) possess multiple antibiotic resistance mechanisms including producing carbapenemases (carbapenemase-producing Enterobacterales [CPE]).[3] Examples

include *Klebsiella pneumoniae* carbapenemase (KPC), oxacillinase-48 (OXA-48) types, and class B Metallo-β-lactamases (MBLs), veronica integron Metallo-beta-lactamases (VIM), imipenemase (IMP) and New Delhi Metallo-β-lactamase-1 (NDM-1).[3] Antimicrobials are broken down by these carbapenemase enzymes, which prevent them from killing bacteria.[3] Carbapenemase genes are carried on plasmids (mobile genetic components) that facilitate resistance mechanisms between organisms against various antibiotics such as fluoroquinolones, cephalosporins, aminoglycosides, polymyxins, tetracyclines, and others.[4] It is therefore difficult to treat CREs since there are very few antimicrobial options available to which these organisms may be susceptible.[4]

Infections caused by CRE are increasing in South Africa (SA), causing substantial morbidity and mortality.[5] An in-hospital crude mortality ratio associated with CRE bloodstream infection is 38%, and the case fatality ratio is as high as 52% among children.[6-7]

Antimicrobial resistance surveillance in South Africa

The NICD conducts national GERMS-SA surveillance for laboratory-based, healthcare-associated antimicrobial resistance (AMR) pathogens. GERMS-SA surveillance data provides an accurate baseline from which appropriate prioritization, planning of programs, and actions can be taken to protect and promote the health of the public. This surveillance system aims to monitor AMR trends, phenotypically and genotypically characterize pathogens, perform antimicrobial susceptibility testing, and detect and manage outbreaks caused by healthcare-associated infections (HAI) pathogens.

Carbapenem-resistant Enterobacterales surveillance system

CHARM conducts CRE bloodstream infection surveillance in 13 public and private enhanced surveillance sites (ESS) across five South African provinces. This surveillance was previously evaluated after its conception in 2016.[8] The system was reported to be simple, useful, timely, and acceptable although areas of improvement were recommended.[8]

GERMS-SA CRE bloodstream infection enhanced surveillance system description

The sentinel site laboratories (National Health Laboratory Service (NHLS)), GERMS-SA, and CHARM are all stakeholders of the CRE surveillance system. The clinicians and laboratory staff, medical technologists, microbiologists, pathologists at the sentinel sites, GERMS-SA surveillance officers (SOs), programme

coordinators, administrators, epidemiologists, data managers, medical technologists, medical scientists, and pathologists all play important roles in ensuring that CRE cases are identified, captured, and reported by the surveillance system.

Case definition

A CRE case was classified as any hospitalised patient with an Enterobacteriaceae isolate from a blood culture specimen that is resistant to any of the carbapenems. Only the first episode was considered as a case defined as the first CRE-positive specimen within 21 days. When the same CRE was isolated from the same patient after 21 days, it was considered a new case. Patients with isolated distinct CRE species within 21 days of the first positive specimen were considered different cases.

Case identification and reporting

Clinicians request the collection of blood culture specimens from a patient suspected of having a CRE bloodstream infection and send them for culture at the NHLS laboratory. If a pathogen is isolated, the NHLS laboratory sends the isolate on Dorset transport media to CHARM at the NICD.[9] After isolation of CRE, a notification is sent to the SO who locates the patient and completes an electronic case report form (CRF) using a web-based application (MOBENZI) through patient interviews. If the patient has died or has already been discharged, the SO completes the CRF through medical record review. Field project coordinators (FPCs) ensure CRF data quality by checking the completeness of data on the CRF and liaising with SO's for any queries. Both CRF and laboratory data are stored on a GERMS-SA password-protected Microsoft Access database.

Upon receipt of isolates to CHARM, they are checked for eligibility. Duplicate isolates, incorrect specimens, and those that do not meet the case definition are discarded. All eligible isolates are phenotypically characterized, subsequently, carbapenemase genes are identified using genotypically characterization. Isolates are kept for a maximum of three months for further analysis when the need arises. Laboratory results are recorded and stored in a dedicated Microsoft Access database on a dedicated server (Figure 1).

Every quarter (three months), CRE data extracts are requested from the surveillance data warehouse (SDW), a data repository containing laboratory results from all NHLS laboratories. This is a way of identifying audit cases, whereby CRFs were not completed or isolates were not submitted to CHARM.

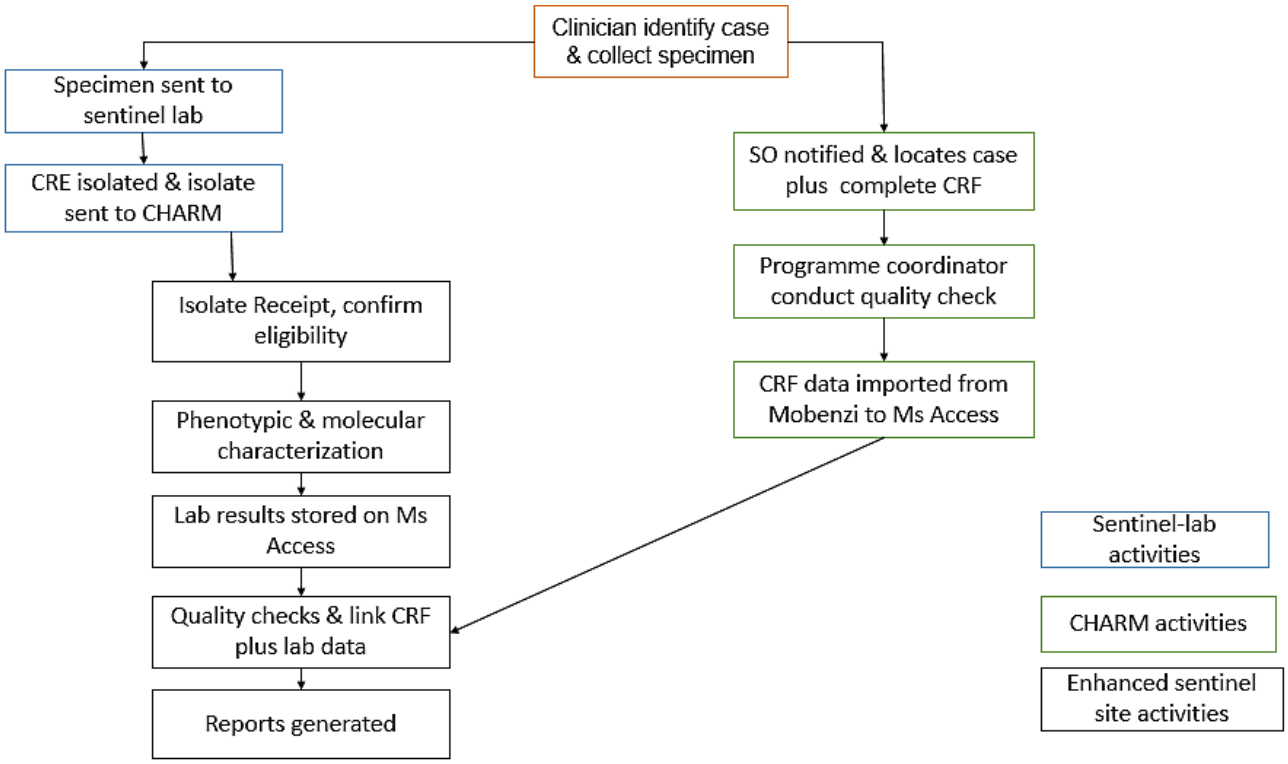

Figure 1. GERMS-SA carbapenem-resistant Enterobacterales bloodstream infection surveillance system flow chart.

Lab: NHLS laboratory. MS: Microsoft. CRF: Case report form. SO: Surveillance officer. CRE: carbapenem-resistant Enterobacterales. CHARM: Centre for Healthcare-Associated infections, Antimicrobial Resistance and Mycoses.

Aim and objectives of the GERMS-SA CRE surveillance system evaluation

This project aimed to evaluate the GERMS-SA CRE surveillance system and compare the findings to those from the baseline 2016 surveillance system evaluation, thereby assessing the need to continue with ongoing CRE enhanced surveillance. The primary objectives were:

1. To describe the clinical and epidemiological characteristics of cases with CRE bloodstream infection at four GERMS-SA enhanced surveillance sites (ESSs) in Gauteng Province from 1 January 2019 to 31 December 2020.
2. To evaluate the GERMS-SA CRE surveillance system attributes as specified in the updated Centers for Disease Control and Prevention (CDC) guidelines: simplicity, timeliness, acceptability,

sensitivity, data quality, and usefulness at these four GERMS-SA ESSs in Gauteng Province from 1 January 2019 to 31 December 2020.

Methods

Study design

This was a mixed-methods cross-sectional study with both quantitative and qualitative components. Qualitative data were collected through a Google Forms online survey that was distributed to participants by email. Participants who did not respond to the email were contacted to complete an alternative paper-based or telephonic interview. The following attributes were evaluated: simplicity, acceptability and timeliness. Stakeholders invited to participate include those who took part in the CRE surveillance system from both surveillance sites and at the NICD: laboratory staff, site investigators, data management team members, SOs, FPCs, medical technologists, medical scientists, clinicians, epidemiologists and pathologists. The quantitative component entailed the extraction of secondary data (1 January 2019–31 December 2020) from the GERMS-SA CRE database. Cases of CRE bloodstream infection were described epidemiologically and data quality, timeliness and usefulness of the surveillance system were evaluated.

Operational case definition

A CRE case was defined as any patient from whom Enterobacterales was cultured from blood and was resistant to ertapenem or any other carbapenem if ertapenem susceptibility testing was not done. If the same organism was isolated from blood in the same patient within 21 days, it was considered a duplicate isolate and excluded.

Study setting

Among the 13 participating NHLS microbiology laboratories and institutions that conducted GERMS-SA CRE surveillance, our study included four ESSs: Chris Hani Baragwanath Academic Hospital, Charlotte Maxeke Johannesburg Academic Hospital, Steve Biko Academic Hospital and Dr. George Mukhari Hospital (Figure 2).

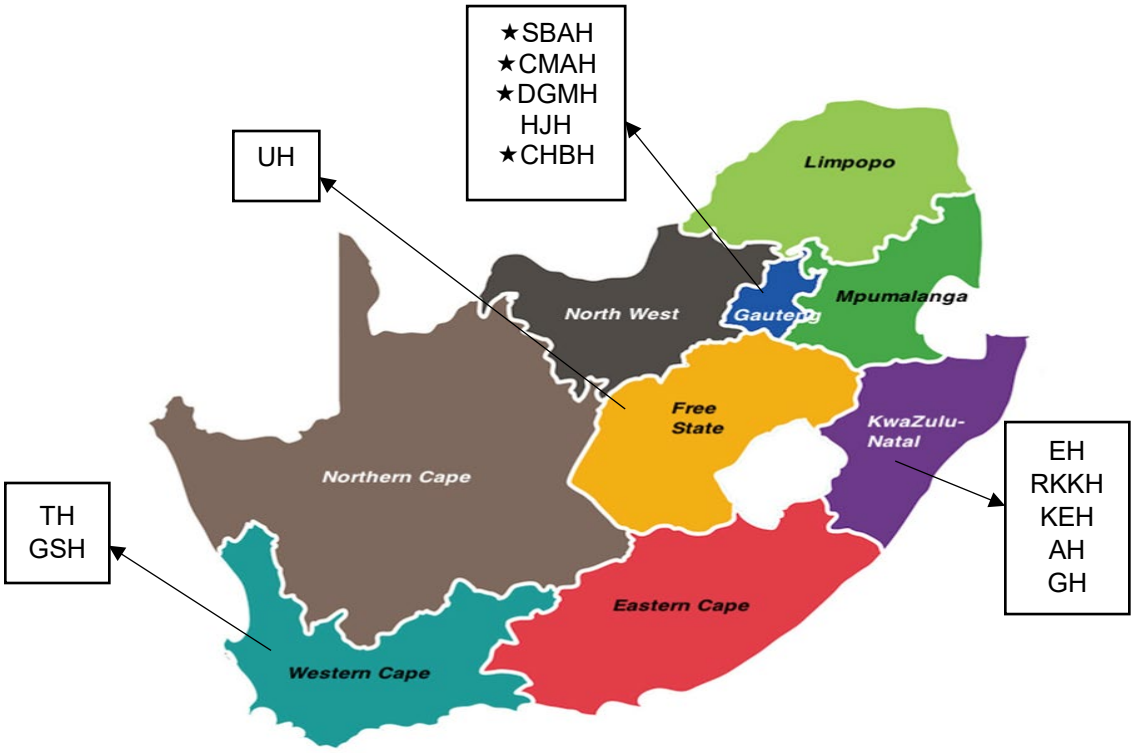

Figure 2. GERMS-SA carbapenem-resistant Enterobacterales surveillance sentinel sites by province, South Africa.

SBAH: Steve Biko Academic Hospital. CMAH: Charlotte Maxeke Johannesburg Academic Hospital. CHBH: Chris Hani Baragwanath Hospital. HJ: Hellen Joseph Hospital. UH: Universitas hospital. DGMH: Dr.George Mukhari. TH: Tygerberg Hospital. GSH: Groote Schuur Hospital. EH: Edendale. RKKH: RK Khan Hospital. KEH: King Edwards Hospital. AH: Addington. GH: Grey Hospital.

★ Enhanced surveillance site under evaluation

Data management

Questionnaire responses were extracted from the Google Forms database and imported into MS Excel (Microsoft Corporation, USA). In addition, we extracted data from January 2019 to December 2020 from the GERMS-SA MS Access database (Microsoft Corporation, USA) and imported it into MS Excel. Data cleaning and analysis were carried out using Stata Corp LLC version 17.

Data analysis

For the quantitative analysis, cases of CRE bloodstream infections were described using frequency distributions, percentages, and graphs. Surveillance system attributes defined in Table 1.

Table 1. Definitions and assessment criteria for GERMS-SA surveillance system attributes, South Africa 2019 – 2020.

Attribute	Definition of attribute	Type of assessment and analysis conducted
Simplicity	The structure and ease of GERMS-SA CRE surveillance operation.	Measured the amount of time required to identify a case, collect and manage data. Among trained participants, we assessed the need for further training required and the simplicity of the case definition.
Timeliness	The delay between the steps in the system and the availability of data for action.	Timelines and turnaround times between the following surveillance activities were assessed. **CRE diagnosis to isolate receipt at CHARM:** Date at which the CRE isolate was received at CHARM minus date of CRE result at the NHLS laboratory**.** **Isolate receipt at CHARM to phenotypic characterization**: Date the which minimum inhibitory concentration (MIC) test was done at CHARM minus the date at which the isolate was received at CHARM. **CRE diagnosis to CRF completion:** Date of CRF completion minus date of CRE result at NHLS laboratory. Median days and corresponding interquartile range (IQR) were assessed.
Acceptability	The willingness of the CRE surveillance stakeholders to participate in the system.	We assessed the participants' knowledge and attitudes towards participating in the surveillance system. We asked participants to describe how difficult it was to complete the CRF by using a scale of one to five, one being the least difficult and five being very difficult.
Data quality	A reflection of the completeness and validity of the data in the surveillance system.	We assessed the percentage (%) of missing data among important variables including clinical, demographic data and laboratory data
Usefulness	Whether or not the system contributes to the prevention and control of CRE infections. Whether the system provides estimates of morbidity and mortality, identifies disease risk factors, and stimulates research.	We conducted an internet search of any CRE NICD published guidelines, policy documents, communique, bulletins, or reports published. We also asked participants if they had ever received any reports with analyzed data.

Ethical considerations

Ethical approval to conduct this study was obtained from the Faculty of Health Sciences Research Ethics Committee, University of Pretoria (118/2021). Further permission to use data was obtained from data gatekeepers at GERMS-SA and CHARM/NICD. The participants that consented to be part of the study were enrolled anonymously using unique identifiers during data analysis.

Results

Using the operational case definition, 1 266 CRE cases were identified from the four selected ESSs in Gauteng Province during the period 1 January 2019 to 31 December 2020 (Figure 3).

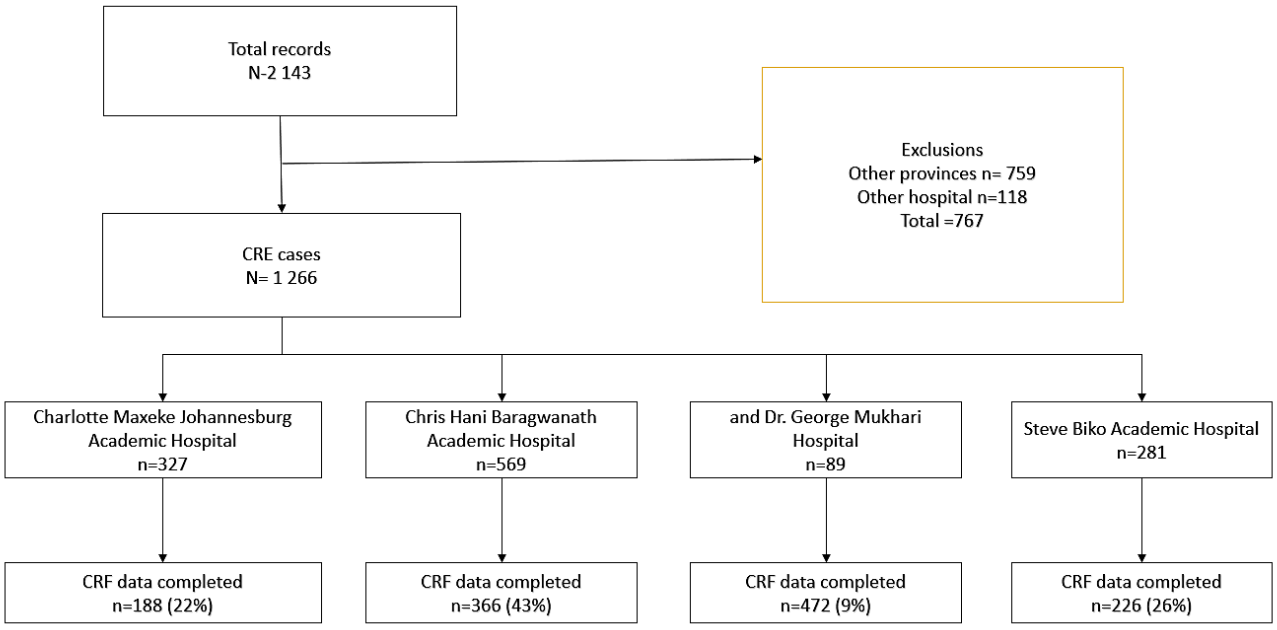

Figure 3. Carbapenem-resistant Enterobacterales surveillance cases from four GERMS-SA sentinel sites, Gauteng Province, January 2019–December 2020.

Other hospitals: Helen joseph / Coronation / Rahima Moosa Mother and Child Hospital, Tshwane District Hospital, Zola-Jabulani District Hospital, Nelson Mandela Children Hospital. Other provinces: Free State, Western Cape, KwaZulu-Natal.

Of the 1 266 CRE cases, 31% (n=389) were older than 50 years and males accounted for 53% (n=673). Forty-six percent (n=569) of cases were reported from Chris Hani Baragwanath Academic Hospital followed by 26% (n=327) from Charlotte Maxeke Johannesburg Academic Hospital. Twenty-six percent (n=334) had an intravenous line inserted at diagnosis. Cases that underwent surgery before a positive blood culture accounted for 15% (n=194), and 21% (n=264) of cases were mechanically ventilated at the time of blood culture. Five percent (n=64) of cases had a known history of previous hospital admission and 28% (n=365) of cases received antibiotics in the last six months of admission. Hospital outcome was known for 64% (n=810), of whom 38% (n=310) died (Table 3).

Table 2. Demographic and clinical characteristics of 1 266 cases of carbapenem-resistant Enterobacterales infection at 4 GERMS-SA sentinel sites, Gauteng Province, January 2019–December 2020.

Characteristics	**Frequency (N=1266)**	
Demographic characteristics	**n**	**%**
Age		
Median (IQR)	35 years (IQR 17–52 years)	
Sex		
Female	583	46
Male	673	53
Unknown	10	1
Clinical characteristics		
Medical device at the time of positive blood culture		
Intravenous line	334	26
Urinary catheter	135	11
Intra-arterial line	52	4
Drainage port	22	2
Central venous line	3	0.2
Other medical devices	141	11
Unknown	579	45
Received antibiotics in the past 6 months of current admission		
No	359	28
Yes	365	28
Unknown	542	42
Comorbidities		
HIV-infected	155	12
Malignancy	93	7

Diabetes	44	3
Renal disease	40	3
Cardiovascular disease	9	1
Unknown	925	73
Mechanical ventilation at the time of positive blood culture		
No	491	39
Yes	264	21
Unknown	414	40
Source of infection		
Skin/ soft tissue infection	142	22
Lower respiratory tract infection	122	19
Abscess	15	2
Central nervous system	20	3
Bone/ joint infection	4	1
Other	63	10
Unknown	275	43
Previous hospital admission in the last year		
No	623	49
Yes	64	5
Unknown	579	46
Hospital of diagnosis		
Charlotte Maxeke Johannesburg Academic	327	26
Chris Hani Baragwanath	569	46
Steve Biko Pretoria Academic	281	22
Dr. George Mukhari	89	8
In-hospital outcome		
Alive[a]	500	39
Dead	310	24
Unknown	456	36

[a] refused hospital admission, recovered, discharged, still admitted, transferred.

CHARM received 709 isolates from the sentinel laboratories (NHLS). Of those, 86% (609/709) were viable. Of the 609 organisms identified, *Klebsiella pneumoniae* accounted for the majority of organisms (80%, n=491) followed by *Enterobacter cloacae* (5%, n=38), and the least common organisms were *Enterobacter aerogenes* and *Proteus* species (<1%, n=1) (Table 4).

Table 3. Carbapenem-resistant Enterobacterales organisms identified by the GERMS-SA CRE surveillance system, Gauteng Province sentinel sites, January 2019–December 2020.

Organism	**n**	**%**
Klebsiella pneumoniae	491	81
Enterobacter cloacae	38	6
Serratia marcescens	25	4
Escherichia coli	23	4
Klebsiella pneumoniae species	22	4
Enterobacter species	8	1
Citrobacter freundii	1	0.2
Providencia rettgeri	1	0.2
Total	**609**	**100**

Klebsiella pneumoniae: Klebsiella pneumoniae ESBL, Klebsiella pneumoniae sssp, pneumoniae; Klebsiella pneumoniae species*: Klebsiella pneumoniae variicola, Klebsiella pneumoniae aerogenes, Klebsiella pneumoniae ozaenae, Klebsiella pneumoniae oxytoca; Enterobacter* species*: Enterobacter kobei, Enterobacter asburiae.*

Of the cases identified by the CRE bloodstream infection surveillance at the four Gauteng sentinel sites, 43% (n=556/1 266 were reported as audit (no isolates sent to CHARM). Of the CPE genes identified in this study, the majority were PCR-positive for OXA-48 & variants (71%, n=434), followed by NDM (11%, n=70). The least common CPE gene identified was KPC at <1% (n=3) (Figure 4).

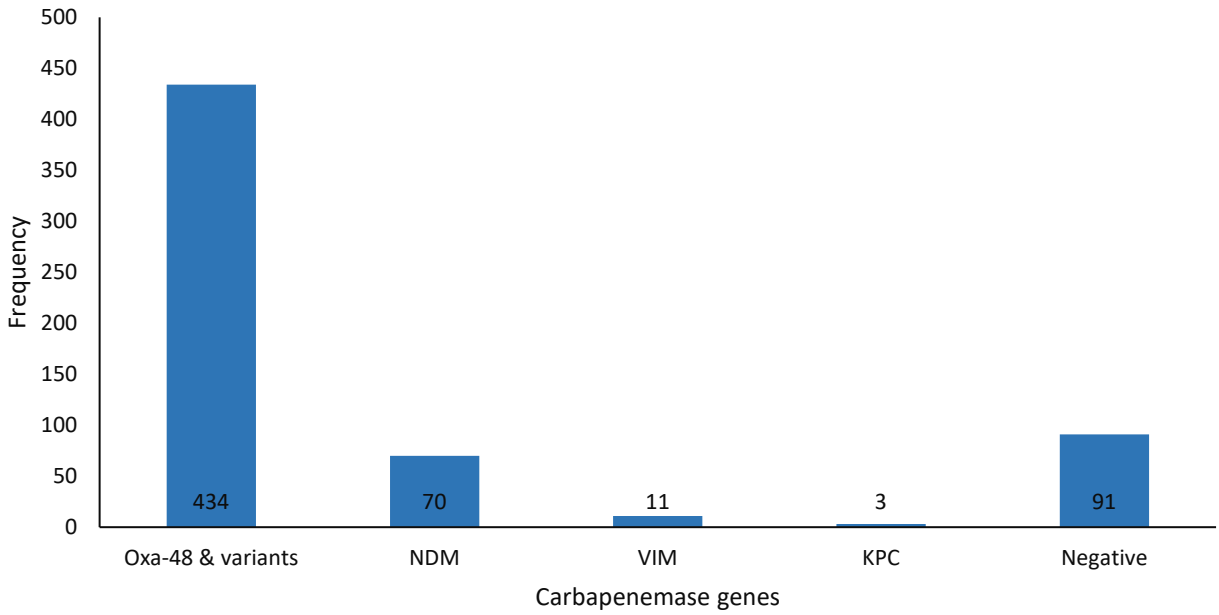

Figure 4. Distribution of carbapenemase genes of 609 carbapenem-resistant Enterobacterales isolates at four GERMS- SA sentinel sites, Gauteng Province, January 2019–December 2020.

OXA: Oxacillinase; NDM: New Delhi metallo-beta-lactamase; VIM: veronica integron Metallo-beta-lactamases type; KPC: *Klebsiella pneumoniae* carbapenemase.

Surveillance system attributes

Simplicity

Of the 40 questionnaires that were distributed to staff, 65% (n=26) consented to participate. Five participants responded to a paper-based and in-person interview, while the remaining 21 participants responded to the online Google Forms survey. The majority of participants were from Chris Hani Baragwanath 36% (n=8), followed by GERMS-SA 32% (n=7) and Charlotte Maxeke Johannesburg Academic Hospital 23% (n=5). Medical technologists from CHARM and surveillance sites comprised the majority of respondents 41% (n=9), followed by surveillance officers 23% (n=5). Most participants were female 86% (n=19).

Of the total participants, 86% (n=16) reported that the case definition was easy to understand, and 14% (n=3) reported that the case definition was difficult to understand but did not specify a reason. Among all participants, 68% (17/26) reported that they had been trained on the system, and this percentage was

higher compared to the previous GERMS-SA CRE 2016 evaluation of 44% (14/32). Among those who were trained, 17% (4/24) reported they would appreciate further training; this percentage was lower than the previous evaluation of 70% (7/10).

Eighty-six percent (18/22) of participants correctly identified blood culture as the specimen used to diagnose CRE according to the case definition, this percentage is higher than the previous evaluation finding of 37% (7/18).

Acceptability

About 87% (21/24) of the participants were familiar with the GERMS-SA CRE surveillance system and this percentage was higher than the previous evaluation (84%, 27/32). The majority of participants (58%, 15/26) reported that CRE infections were a significant cause of morbidity and mortality, but this percentage was lower than the previous evaluation with 84% (27/32).

About 96% (25/26) of the participants correctly identified the route of CRE transmission (person-to-person). This percentage was higher than in the previous evaluation where the mode of transmission was correctly identified by 53% (17/32) of participants.

About 77% (20/26) of participants reported that they played a role in the CRE surveillance system and 92% (22/24) reported that the role they played was their responsibility; this percentage was higher than the previous evaluation of 89% (17/19). Sixty-three percent (15/24) of participants reported that their roles did not require a lot of effort, and this percentage was lower than the previous evaluation of 78% (15/19).

Surveillance officers reported that the time taken to complete a CRF was less than 15 days. Two of the five participants reported that CRFs were difficult to complete. On a scale of one to five, one being easy and five being very difficult, both of the participants chose three (average). The reason for their response was that the dates for invasive devices were often missing from patients' files. Five out of 11 participants agreed that data were readily available, while 27% (3/11) reported that they were not sure if data were readily available. One participant disagreed that data were readily available for public health action.

Timeliness

The median time taken from CRE diagnosis to receipt of isolates at the surveillance laboratory was 9 days (IQR 5–14 days), which was longer than the previous evaluation of 6 days (IQR 3–11 days). The median time from receipt of isolates by the surveillance laboratory to phenotypic characterization was 15 days (IQR 7–53 days) and was longer than the previous evaluation of 5 days (IQR 2–7 days). The duration between a CRE diagnosis at a sentinel laboratory to CRF completion was longer (median of 58 days; IQR 9–158 days) compared to the previous evaluation (median 12 days; IQR 8–16 days) (Figure 4).

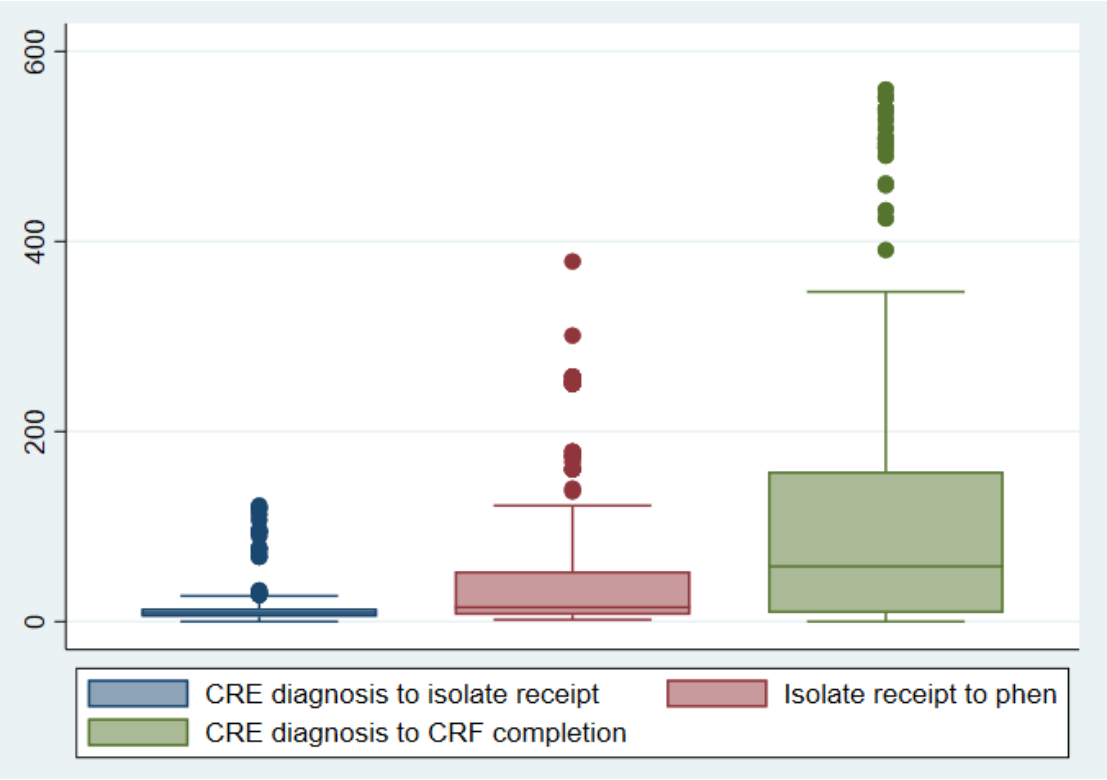

Figure 4. Duration between steps of the carbapenem-resistant Enterobacterales surveillance system in Gauteng Province, January 2019 – December 2020.

CRE: Carbapenem-resistant Enterobacterales: Case report form. Phen: phenotypic characterisation
CRE diagnosis to isolate receipt: 9 days (IQR 5-14). CRE diagnosis to CRF completion: 58 days (IQR 9-158). Isolate receipt to phonotypic characterization 15 days (IQR 7-53).

Data quality

Of the 1 266 cases reported from the four ESS, 67% (n=852) had complete clinical data, this percentage was lower than the previous surveillance where 84% (153/182) of cases had complete clinical data. Among demographic variables, the date of birth was the least completed with 2% (n=17) missing data, followed by age with 1% (n=10) missing data. The remaining demographic variables namely, sex, province and hospital name were complete for all case-patients. During the previous evaluation, patient race was the least completed, 26% (40/153), followed by age 7% (10/153). Sex, province and hospital name were complete for all records. Our evaluation reported the source of infection for clinical data was the least completed with 32% (n=275) followed by admission date with 31% (n=267). The most incomplete clinical variable was patient outcome with 5% (n=42) of patients missing this information. Ward type was complete for all case patients. During the previous evaluation, admission date and outcome were both the most incomplete variables 19% (29/153), followed by the source of infection, 29% (45/153). The least incomplete variable was ward type, 7% (10/153). Specimen collection date was complete for all case-patients.

Among risk factor variables, comorbidity was the least complete variable with 17% (n=145) missing data, followed by previous hospitalization (16%, n=116). The least completed variable was whether or not the patient was referred from another facility (6%, n=470). During the previous evaluation, the least completed variable was a medical device, 30% (46/153), followed by whether the patient was a health care worker, 28% (43/153), and the least incomplete variable was the specified medical device, 1% (1/95). Among laboratory data, organism name was fully completed for viable isolates. The least incomplete risk factor variable was the CRE diagnosis date at 33% (n=245). Previous infections were complete for all the case patients. During the previous evaluation, CRE diagnosis was the most incomplete, 19% (29/153), while the least incomplete was organism name, 4% (6/153). Previous infections and carbapenem genes were complete for all the records (Table 6).

Table 4. Quality of data for the carbapenem-resistant Enterobacterales surveillance system at four GERMS-SA sentinel sites, Gauteng Province, January 2019 – December 2020.

Variable	Cases with missing data	
	n=852	%
Demographic		
Age	10	1
Sex	0	0
Province	0	0
Hospital name	0	0
Date of birth	17	2
Clinical		
Admission date	267	31
Ward type	69	8
Specimen collection date	0	0
Source of infection	275	32
Outcome	42	5
Risk factors		
Comorbidity	145	17
Medical devices	86	11
Mechanical ventilation	97	10
Previous hospital admission	116	16
Previous exposure to antibiotics	128	14
Referred from another facility	63	6
Laboratory		
CRE diagnosis date	245	33
Organism name	0	0
Carbapenem resistance genes	417	45
Previous organism isolated	0	0

Usefulness

Based on the system database analysis, the information collected was enough to fulfill the system's objectives. Sufficient information on demographic, clinical, and other epidemiological characteristics of CRE cases was collected by the system. Publications (n=3), bulletin articles (n=9), and yearly CRE surveillance reports (n=5) were discovered through an online search.

About 76% (19/25) of participants were not aware of what was done with the data collected by the system. This percentage was higher than the last surveillance evaluation at 68% (21/31). Fifty percent (13/26) of the participants reported having never received any feedback or reports presenting data

collected by the CRE surveillance system. This percentage was lower than it was during the initial surveillance evaluation at 74% (23/31). All participants reported that they would welcome reports or publications and this finding was higher than it was during the previous surveillance evaluation at 90% (17/19).

Discussion

CREs remain one of the leading causes of healthcare-associated infections globally, and SA monitors CRE patterns and their implications in the healthcare system as recommended by the WHO[9-11]. The overall performance of various CRE surveillance systems in four Gauteng ESS in comparison with the earlier system evaluation had improved, although some components worsened. The NICD GERMS-SA CRE surveillance system was found to be useful as there were bulletin reports, published articles, and annual GERMS-SA CRE surveillance reports identified through an internet search and on the NICD website.[12-16] However, more than 75% of the participants never knew why the data were collected and none had received any reports.

There was an overall sub-optimal survey response rate from participants and some were not willing to participate during this surveillance system evaluation. This may have negatively impacted the generalizability of the results. The knowledge of the clinical site from which CRE should be isolated for a case to be included in the surveillance system was good. Participants not receiving feedback and reports on the work they do may also affect work morale, productivity, and the enthusiasm of system users. This may also be the reason behind the poor attitude towards participating in this surveillance system evaluation. Another contributing factor is that new employees may have not been trained or orientated on the CRE surveillance system.

Completeness of data particularly on important variables which include demographic, clinical, risk factors, and laboratory variables guides adequate analysis and inference of the study findings to the population of interest. Of the overall cases reported in the four Gauteng ESS, there was a lower proportion of CRF completed than in previous surveillance system evaluations. In our evaluation, there were some missing values among demographic, clinical, laboratory, and risk factors variables but the proportion of missing data was lower compared to the previous evaluation.

The latest annual report published by the NICD showed increasing CRE prevalence and CRE-associated mortality, highlighting the increasing health burden these organisms pose on the public health care system.[17] Timeliness of the surveillance system may assist with identifying and controlling for healthcare-associated outbreaks, and may inform guidelines on CRE prevention measures. The system evaluation reported longer durations between the steps of the surveillance system; the median days from time CRE diagnosis to receipt of isolates at surveillance laboratory, from when isolates were received by the surveillance laboratory to phenotypic characterization as well as from CRE diagnosis at a sentinel laboratory to CRF completion. The poor system timeliness compared to the previous surveillance system evaluation may have been attributed to the COVID-19 pandemic interruptions, particularly during the national lockdown.[18]

Our CRE surveillance system evaluation at Gauteng ESS showed that the most predominant organism causing CRE infections was *K. pneumoniae* followed by *E. cloacae,* which was consistent with a previous report published in SA where *K. pneumoniae* accounted for 80% of isolates followed by *S. marcescens.* The most predominant CPE genes circulating in Gauteng during the evaluation period were OXA-48 & its variants and NDM. This is consistent with a previously published South African CRE report in 2018, which found OXA-48 and its variants & NDM to be the most predominant CPE genes identified.[5]

Findings from the descriptive analysis showed that more than a quarter of the cases died. These findings are consistent with GERMS-SA 2019 annual report that reported a 38% mortality rate.[17] Since our study employed descriptive analysis, we, therefore, report all-cause mortality and there may have been other factors that contributed to these hospital deaths yet we could not account for them. We also described demographic clinical characteristics but could not establish risk factors for CRE bloodstream infections in Gauteng ESS. An analytical study is recommended to explore mortality and risk factors associated with CRE bloodstream infections.

Conclusions

The evaluation study showed that the GERMS-SA CRE surveillance system in the Gauteng Province among four ESS is not operating efficiently. Although some of the system's components have improved from the initial evaluation, the response rate, overall CRF completed and timeliness during this evaluation worsened. The poor survey response rate suggests the need for ongoing training. The majority of sentinel laboratory staff had no access to the online published reports, hence poor knowledge of the usefulness

of surveillance data collected suggests the need for non-electronic dissemination of surveillance system findings. Surveillance for CRE should continue in different formats such as periodic surveillance.

Limitations

Not all public health system evaluation system attributes were evaluated in this study. The poor response rate to the survey may affect the generalizability of the findings.

Recommendations

The evaluation identified areas that could be improved including:

- Regular feedback to stakeholders at the end of every quarter
  - Feedback can be written in the form of a newsletter and orally communicated at all sentinel sites (updates during regular morning staff meetings).
  - Feedback should include the burden and trends of the CREs. Most importantly, the role that the surveillance system plays should be emphasized and reports on the work done should be produced. These should include public health importance and implications for the surveillance system.
- Ongoing, training of stakeholders to mitigate problems caused by regular staff turnover.
- Improved data collection as all risk factor variables, and some demographic and clinical variables were not fully completed, resulting in poor data quality.
- Improved timeliness between surveillance steps to ensure that the enhanced surveillance system operates more efficiently.
- Establishment of periodic surveillance for CRE going forward.

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References

1. Tunyong W, Arsheewa W, Santajit S, Kong-Ngoen T, Pumirat P, Sookrung N, *et al*. Antibiotic resistance genes among carbapenem-resistant *Enterobacterales* (CRE) isolates of Prapokklao hospital, Chanthaburi Province, Thailand. *Infection and Drug Resistance*. 2021; 14:3485-94. doi:10.2147/IDR.S328521
2. Ramalingam S, Ramesh S. Simplified protocol for the phenotypic identification of carbapenem resistance mechanism in *Enterobacteriaceae*. *Journal of Clinical and Diagnostic Research* [Internet]. 9(10): DL01. [Cited Access Year Access Date|] |. Available from: URL;https://univofpretoria.on.worldcat.org/v2/search/detail/8653899793?queryString=Simplified%20Protocol%20for%20the%20Phenotypic%20Identification%20of%20Carbapenem%20Resistance%20Mechanism%20in%20Enterobacteriaceae&clusterResults=true&groupVariantRecords=false
3. Ben Abderrazek R, Chammam S, Kouri A, Perilli M, Dhaouadi S, Mdini I, *et al*. Inhibitory potential of polyclonal camel antibodies against new Delhi Metallo-β-lactamase-1 (NDM-1). *Molecules* (Basel, Switzerland). 2020; 25(19) DOI: 10.3390/molecules25194453
4. World Health Organization. Report on the burden of endemic Healthcare-Associated Infection worldwide. 2011; Available from: https://apps.who.int/iris/bitstream/handle/10665/80135/9789241501507_eng.pdf
5. Singh-Moodley A, Perovic O, Ismail H. An overview of antimicrobial resistance surveillance among Healthcare-Associated pathogens in South Africa*. African Journal of Laboratory Medicine*. 2018; 7(2):1-6.
6. Perovic O, Ismail H, Quan V, Bamford C, Nana T, Chibabhai V, *et al*. Carbapenem-resistant *Enterobacteriaceae* in patients with bloodstream infection at tertiary hospitals in South Africa, 2015 to 2018. *Eur J Clin Microbiol Infect Dis*. 2020:1-8.
7. Nabarro LE, Shankar C, Pragasam AK, Mathew G, Jeyaseelan V, Veeraraghavan B, *et al*. Clinical and bacterial risk factors for mortality in children with carbapenem-resistant *Enterobacteriaceae* bloodstream infections in India. *The Pediatric Infectious Disease Journal*. 2017; 36(6):e161-e6.
8. Quan V [Internet]. GERMS-SA link newsletter volume 53, August 2017. 2017. Available from:https://www.nicd.ac.za/wp-content/uploads/2017/03/LINK-53-August-2017-Final-00000002.pdf.

9. Quan V. GERMS-SA: Laboratory-based surveillance for pathogens of public health importance in S45.South Africa [Unpublished]. 2015.
10. Bartsch S, McKinnell J, Mueller L, Miller L, Gohil S, Huang S, *et al*. Potential economic burden of carbapenem-resistant Enterobacteriaceae (CRE) in the United States. *Clin Microbiol Infect.* 2017; 23(1):48. e9-. e16.
11. Pecora ND, Li N, Allard M, Li C, Albano E, Delaney M, *et al*. Genomically informed surveillance for carbapenem-resistant Enterobacteriaceae in a health care system. *ACM Journal*. 2015; 6(4):e01030-15.
12. Mitgang EA, Hartley DM, Malchione MD, Koch M, Goodman JL. Review and mapping of carbapenem-resistant Enterobacteriaceae in Africa: Using diverse data to inform surveillance gaps. *Int J Antimicrob Agents.* 2018; 52(3):372-84.
13. GERMS-SA [Internet]. National Institute for Communicable Diseases Annual Review 2017/18. 2022. Available from: https://www.nhls.ac.za/wp-content/uploads/2019/08/NICD_Annual_Review_2017_18.pdf
14. Brooke B [Internet].]. National Institute for Communicable Diseases Public Health Surveillance Bulletin. 2017. Available from. https://www.nicd.ac.za/wp-content/uploads/2017/03/NICD-Bulletin-Vol_15_Iss3-November_2017.pdf.
15. O Perovic VCAS-M [Internet]. Clinical update molecular detection of carbapenemase-producing genes in referral Enterobacteriaceae in South Africa: A short report. 2021.http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S0256-95742016001000016
16. O. P, Ismail H, Quan V, Bamford C, Nana T, Chibabhai V, *et al*. Carbapenem-resistant Enterobacteriaceae in patients with bacteremia at tertiary hospitals in South Africa, 2015 to 2018. European Journal of Clinical Microbiology & Infectious Diseases: official publication of the *European Society of Clinical Microbiology*. 2020; 39(7) doi:10.1007/s10096-020-03845-4
17. Lebaka TQV [Internet]. GERMS-SA: Annual surveillance review 2019. Johannesburg, South Africa: GERMS-SA; 2021 [cited 2019 January 2020].Available from: https://www.nicd.ac.za/wp-content/uploads/2021/02/GERMS-Annual-Review-2019.pdf.
18. Mbunge E. Effects of COVID-19 in South African health system and society: An explanatory study. *Diabetes Metab Syndr*. 2020 Nov-Dec;14(6):1809-1814. DOI: 10.1016/j.dsx.2020.09.016. Epub 2020 Sep 11. PMID: 32956925; PMCID: PMC7485444.

PARALYSIS SURVEILLANCE FOR POLIO, SOUTH AFRICA, AND OTHER AFRICAN COUNTRIES, 2020

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Summary

From January 2020 to December 2020, the South African national non-polio acute flaccid paralysis rate was 2.6/100 000 children under 15 years compared to 3.5/100 000 children in 2019. The country reached the World Health Organization target of 2.0/100 000 population under the age of 15, but did not reach the country's target of 4.0/100 000. Receipt of samples in the laboratory within 72 hours of collection was 36%, below the World Health Organization's target of 80%. No wild-type poliovirus nor vaccine-derived poliovirus was detected in South Africa. Sabin poliovirus type 2 and circulating vaccine-derived poliovirus type 2 (cVDPV2) were detected from 13 African countries, namely Burkina Faso, Angola, Malawi, Ethiopia, Senegal, Côte d'Ivoire Niger, the Democratic Republic of the Congo, Republic of South Sudan, Zambia, Guinea, Sierra Leone and Mali. Sabin 2 and cVDPV2 were the most prevalent poliovirus strains in the African region. The performance of AFP surveillance in 2020 has declined despite the fact that South Africa has achieved the WHO target. There is an urgent need for more African countries to use novel oral poliovirus 2 vaccines to prevent cVDPV2 outbreaks. The percentage of South African samples arriving at

the laboratory within 72 hours was below the WHO target. There is also an urgent need to improve the logistics of sample transportation to the laboratory within the required time. As the Global Polio Eradication Initiative winds down and devolves to regional WHO initiatives, incorporation of national AFP surveillance targets into integrated disease surveillance will require attention.

Introduction

The National Institute for Communicable Diseases (NICD) serves as the national polio reference laboratory for acute flaccid paralysis (AFP) surveillance in South Africa and other southern African countries, namely Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia and Swaziland. The NICD additionally serves as the regional reference centre for the polio laboratory network of the World Health Organization (WHO) and conducts molecular characterization of poliovirus isolates from within the African Region.

In 1988, when the Global Polio Eradication Initiative (GPEI) was established, there were an estimated 350 000 cases of wild poliovirus (WPV) types 1, 2, and 3 in more than 125 endemic countries.[1] The global incidence of polio has decreased by 99.9% since then. Two of three wild poliovirus strains are declared globally eradicated: wild poliovirus type 2 in September 2015 and wild poliovirus type 3 in October 2019. In 2020, the African region was declared and certified free of wild poliovirus, a key milestone.[2] Afghanistan and Pakistan are the only two remaining polio-endemic countries in the world, recording 140 wild polioviruses type 1 in 2020.[3] In South Africa, the last wild poliovirus case occurred in 1989.

Many African countries are faced with circulating vaccine-derived poliovirus type 2 (cVDPV2) outbreaks, possibly arising from the emergency use of monovalent oral polio vaccine serotype 2 (mOPV2) during outbreak responses in populations with low coverage of inactivated polio vaccine (IPV). In November 2020, the WHO received an Emergency Use Listing for the use of novel oral polio vaccine serotype 2 (nOPV2) to halt the spread of cVDPV2. The switch from mOPV2 to nOPV2 will significantly reduce the risk of cVDPV2. The nOPV2 vaccine is a modified version of the existing mOPV2, providing comparable protection against poliovirus while being more genetically stable and less likely to revert into a form that can cause paralysis in low immunity settings.[4]

In December 2019, the novel SARS-CoV-2 coronavirus caused a global COVID-19 pandemic. South Africa reported the first COVID-19 case on 05 March 2020 followed by a national lockdown on 27 March 2020. The national lockdown restricted movement that had a notable impact on AFP surveillance.

The aim of this surveillance project was to report the performance of acute flaccid paralysis and environmental surveillance conducted at the National Institute for Communicable Diseases, Johannesburg in 2020.

Methods

Surveillance indicators

AFP case-based surveillance is conducted nationally in South Africa. An AFP case is defined as acute weakness or paralysis with reduced muscle tone, including Guillain-Barré syndrome, in a person under 15 years of age for any reason other than severe trauma, or paralytic illness in a person of any age in which polio is suspected. AFP Surveillance comprises field and laboratory components.

Field surveillance

Cases of AFP from all health facilities were notified to the NICD with samples collected for investigation and completion of case investigation forms. An adequately investigated case required the collection of two stool specimens from an AFP case within 14 days of onset of paralysis. The stool samples should be collected 24-48 hours apart and transported on ice to arrive at the NICD laboratory within 72 hours of collection. AFP cases were detected through active field surveillance, selecting children under the age of 15 years. The WHO non-polio AFP target detection rate for 2020 was 2.0/100 000, while the South African target was 4.0/100 000. For inadequately investigated AFP cases, the National Polio Expert Committee (NPEC) met quarterly for final classification of cases using clinical case notes (Table 1).

Laboratory methods

Virus isolation was performed by inoculation of clarified faecal material into cell cultures, followed by microscopic examination of the cells for cytopathic effect, which indicates the presence of suspected poliovirus/es. Intratypic differentiation (ITD) by polymerase chain reaction (PCR) was conducted on suspected poliovirus isolates. Poliovirus type 2 or discordant Sabin-like polioviruses were sequenced to classify them as either WPV, Sabin or VDPV.

Environmental surveillance

Environmental surveillance, a supplement to AFP surveillance, was initiated in South Africa in July 2019. In 2020, South Africa expanded polio environmental surveillance to include two sites from each of the eight metropolitan districts, totalling sixteen sites in South Africa. All sites collected sewage samples once a month, meeting the minimum WHO requirements.[5] Results for environmental surveillance are shown in figure 1.

Table 1. Polio case classification system used by South Africa's National Polio Expert Committee (NPEC).

STATUS	CLASSIFICATION	CODE	REASON
FINAL	Confirmed (wild type)	A1	Wild-type poliovirus found in a stool sample of a case or one of the
	Confirmed (vaccine-associated)	B1	Vaccine-type poliovirus found in a stool sample of the case, which has residual paralysis at 60-day follow-up; and is confirmed clinically.
	Compatible	C1	AFP case lost to follow-up at 60 days.
		C2	Death related to the illness within 60 days.
		C3	Residual paralysis for which no other medical reason is evident.
	Discarded	D1	No residual paralysis and no wild polio were found in stool samples.
		D2	Confirmed alternative diagnosis
		D3	Non-polio enterovirus isolated.
		D4	No virological investigation and a clinical picture incompatible with polio.
		D5	Two adequate negative stool specimens with 14 days of onset of paralysis
	Denotified	E1	Not an AFP case
PENDING	Inadequate Information	F1	NPEC is unable to make a decision due to the lack of information. The investigating team is given 30 days from the committee meeting to find further details. The final decision is taken at the next NPEC meeting.
	60-day follow-up not yet done	F2	Final decision is referred to the next NPEC meeting for final decision.

Results

South Africa

From 477 AFP cases, 946 stool samples were received for polio isolation, of which 36% were received within 72 hours of collection. Non-polio enteroviruses (NPEVs) were identified in thirty-three samples with a detection rate of 3.5%. Ninety-nine percent of the samples were received on ice, and 94% had results within 14 days.

Samples from four children tested positive for polioviruses. Sabin poliovirus type 1 and/or Sabin poliovirus type 3 were confirmed using Sanger sequencing. Sabin poliovirus type 3 was detected in one case each from Gauteng province, Mpumalanga province and Eastern Cape province, while a fourth child from KwaZulu-Natal Province shed both poliovirus serotypes 1 and 3. No wild-type poliovirus strains nor VDPV were detected in South African samples. Sequencing was performed to determine mutations in the five prime untranslated region of the detected Sabin polioviruses. In three cases, the five prime untranslated region of the detected Sabin poliovirus type 3 had a mutation at position 472 (T472C), a mutation associated with neurovirulence. In one case an additional mutation at position 682 (C682T) was identified in the five prime untranslated region of Sabin poliovirus type 3. One sample was not sequenced at the five prime untranslated region because it had a mixture of poliovirus strains. No children were classified by the NPEC as vaccine-associated paralytic poliomyelitis (VAPP). A summary of the 2020 AFP case classification is listed in Table 2.

Table 2. Final classification of South African Acute Flaccid Paralysis (AFP) cases for 2020.

Classification	Number	Percentage of total (%)
Compatible	5	1.05
Discarded	452	94.76
Denotified (Not AFP)	20	4.19
Total	**477**	**100**

African countries supported by NICD

In 2020, 2102 stool specimens were processed from African countries other than South Africa. From Angola, there were 69 samples (37 cases) in which VDPV2 was identified and 21 samples (11 cases) in which Sabin poliovirus type 2 was detected. One sample from Mozambique tested positive for Sabin

poliovirus type 2. No wild-type poliovirus was detected. The number of samples sequenced from each country is shown in table 4.

Surveillance indicators

South Africa's non-polio AFP rate was 2.6/100 000 children under the age of 15 years. This detection rate was above the WHO target; however, it was below the country's target. Free State Province managed to reach both the country and WHO detection rate targets, while Eastern Cape Province, Gauteng Province, Mpumalanga Province and Western Cape Province met only the WHO target. Provinces that performed below the WHO target were Limpopo, KwaZulu-Natal, Northern Cape and North West (Table 3). This was an unusual year for communicable diseases, with many diseases detected at a lower frequency than previous years, including influenza[6], febrile rash (NICD unpublished data) and hepatitis A.[7] The lower non-polio AFP detection rate than previous years may have been due to fewer circulating non-polio enteroviruses or other infectious causes of AFP due to COVID-19 lockdown restrictions as well as reduced health-seeking behaviour. The national stool adequacy rate was 87.5% and above the required 80% target, similar to the previous year.

Table 3. South African Acute Flaccid Paralysis (AFP) surveillance indicators for 2020 by province and health district.

AFP SUMMARY-WEEK 1-52 OF 2020								
					Key indicators			
Province	**District**	**Total population**	**Under 15 years**	**Target AFP Case**	**Total AFP Cases Under 15 years**	**Non Polio Detection Rate per 100,000 individuals Under 15 years**	**Stool Adequacy (%)**	**Proportion of samples arriving to the lab within 72 hrs from collection (%)**
Eastern Cape	A Nzo DM	887,061	339,805	14	2	0.6	100.0	0.0
Eastern Cape	Amathole DM	985,602	357,846	14	6	1.7	83.3	33.3
Eastern Cape	Buffalo City MM	893,598	278,715	11	1	0.4	100.0	100.0
Eastern Cape	C Hani DM	826,472	272,114	11	11	4.0	72.7	9.1
Eastern Cape	Joe Gqabi DM	379,019	125,683	5	1	0.8	100.0	0.0
Eastern Cape	N Mandela Bay MM	1,333,124	393,304	16	10	2.5	80.0	20.0
Eastern Cape	O Tambo DM	1,525,948	577,804	23	20	3.8	72.7	13.6
Eastern Cape	Sarah Baartman DM	537,461	164,195	7	6	3.7	83.3	33.3
Eastern Cape		**7,368,285**	**2,509,466**	**101**	**57**	**2.3**	**80.7**	**26**
Free State	Fezile Dabi DM	509,520	138,718	6	32	26.0	83.3	38.9
Free State	Lejweleputswa DM	677,535	185,327	7	13	9.2	64.7	52.9
Free State	Mangaung MM	820,955	219,122	9	27	13.7	66.7	43.3
Free State	T Mofutsanyana DM	800,201	240,587	10	13	5.8	78.6	50.0
Free State	Xhariep DM	130,469	33,680	1	1	3.0	100.0	100.0
Free State		**2,938,680**	**817,434**	**33**	**86**	**10.5**	**84.9**	**57**
Gauteng	Ekurhuleni MM	3,643,679	885,634	35	10	1.1	90.0	70.0
Gauteng	Johannesburg MM	5,401,173	1,320,187	53	38	3.0	87.2	74.4

AFP SUMMARY-WEEK 1-52 OF 2020								
						Key indicators		
Province	**District**	**Total population**	**Under 15 years**	**Target AFP Case**	**Total AFP Cases Under 15 years**	**Non Polio Detection Rate per 100,000 individuals Under 15 years**	**Stool Adequacy (%)**	**Proportion of samples arriving to the lab within 72 hrs from collection (%)**
Gauteng	Sedibeng DM	1,003,535	264,894	11	11	4.5	83.3	58.3
Gauteng	Tshwane MM	3,606,241	916,948	37	13	1.7	75.0	50.0
Gauteng	West Rand DM	896,159	231,470	9	5	2.2	100.0	60.0
Gauteng		**14,550,787**	**3,619,133**	**145**	**77**	**2.1**	**90.9**	**63**
KwaZulu-Natal	Amajuba DM	595,573	220,570	9	7	3.2	71.4	14.3
KwaZulu-Natal	eThekwini MM	3,848,515	1,113,002	45	22	2.0	95.5	13.6
KwaZulu-Natal	Harry Gwala DM	526,956	206,957	8	1	0.5	100.0	0.0
KwaZulu-Natal	iLembe DM	724,200	237,541	10	3	1.3	100.0	33.3
KwaZulu-Natal	King Cetshwayo DM	1,016,001	396,218	16	8	2.3	66.7	11.1
KwaZulu-Natal	Ugu DM	799,522	284,563	11	3	1.1	66.7	33.3
KwaZulu-Natal	uMgungundlovu DM	1,191,332	384,977	15	5	1.3	100.0	40.0
KwaZulu-Natal	Umkhanyakude DM	711,176	276,408	11	9	3.6	90.0	30.0
KwaZulu-Natal	Umzinyathi DM	586,402	222,916	9	6	2.7	83.3	16.7
KwaZulu-Natal	Uthukela DM	773,120	304,090	12	11	3.6	90.9	18.2
KwaZulu-Natal	Zululand DM	904,345	337,369	13	2	0.6	100.0	50.0
KwaZulu-Natal		**11,677,142**	**3,984,611**	**159**	**77**	**1.9**	**89.6**	**24**
Limpopo	Capricorn DM	1,358,841	419,721	17	14	3.3	92.9	21.4
Limpopo	Mopani DM	1,247,693	392,541	16	9	2.3	100.0	55.6
Limpopo	Sekhukhune DM	1,266,928	431,488	17	6	1.4	83.3	33.3

AFP SUMMARY-WEEK 1-52 OF 2020								
				Key indicators				
Province	**District**	**Total population**	**Under 15 years**	**Target AFP Case**	**Total AFP Cases Under 15 years**	**Non Polio Detection Rate per 100,000 individuals Under 15 years**	**Stool Adequacy (%)**	**Proportion of samples arriving to the lab within 72 hrs from collection (%)**
Limpopo	Vhembe DM	1,493,306	502,816	20	3	0.6	66.7	0.0
Limpopo	Waterberg DM	733,144	215,671	9	6	2.8	83.3	33.3
Limpopo		**6,099,912**	**1,962,237**	**79**	**38**	**1.9**	**89.5**	**29**
Mpumalanga	Ehlanzeni DM	1,749,011	570,679	23	17	3.0	76.5	58.8
Mpumalanga	G Sibande DM	1,229,321	347,111	14	15	4.3	93.3	53.3
Mpumalanga	Nkangala DM	1,585,460	415,084	17	16	3.9	100.0	37.5
Mpumalanga		**4,563,792**	**1,332,874**	**54**	**48**	**3.6**	**89.6**	**50**
North West	Bojanala Platinum DM	1,779,141	500,932	20	5	1.0	60.0	40.0
North West	Dr K Kaunda DM	780,166	225,511	9	3	1.3	100.0	66.7
North West	Ngaka Modiri Molema DM	977,227	295,675	12	9	3.0	100.0	55.6
North West	Ruth Segomotsi Mompati DM	481,907	174,840	7	0	0.6	0.0	0.0
North West		**4,018,441**	**1,196,958**	**48**	**17**	**1.4**	**88.2**	**41**
Northern Cape	Frances Baard DM	381,764	99,455	4	1	2.0	50.0	0.0
Northern Cape	J T Gaetsewe DM	248,423	77,079	3	0			0.0
Northern Cape	Namakwa DM	113,317	28,069	1	1	3.6	0.0	0.0
Northern Cape	Pixley ka Seme DM	213,607	56,335	2	0	1.8	0.0	0.0
Northern Cape	ZF Mgcawu DM	269,163	63,450	3	1	1.6	100.0	0.0
Northern Cape		**1,226,274**	**324,388**	**13**	**3**	**0.9**	**66.7**	**0**
Western Cape	Cape Town MM	4,233,412	998,210	40	27	2.7	85.2	40.7

AFP SUMMARY-WEEK 1-52 OF 2020								
					Key indicators			
Province	**District**	**Total population**	**Under 15 years**	**Target AFP Case**	**Total AFP Cases Under 15 years**	**Non Polio Detection Rate per 100,000 individuals Under 15 years**	**Stool Adequacy (%)**	**Proportion of samples arriving to the lab within 72 hrs from collection (%)**
Western Cape	Cape Winelands DM	946,248	243,238	10	3	1.2	100.0	66.7
Western Cape	Central Karoo DM	78,205	21,624	1	0			0.0
Western Cape	Garden Route DM	641,957	158,642	6	8	5.0	100.0	25.0
Western Cape	Overberg DM	303,441	72,112	3	3	4.2	66.7	33.3
Western Cape	West Coast DM	478,050	122,832	5	3	2.4	100.0	66.7
Western Cape		**6,681,313**	**1,616,658**	**65**	**44**	**2.7**	**88.6**	**39**
South Africa		**59,124,626**	**17,363,759**	**697**	**447**	**2.6**	**87.5**	**36**

Non-Polio detection rate: red (0-1.99), yellow (2-3.99), green (4+), and blue (no cases reported).

Stool adequacy: red (<80), green (>80), and blue (no cases reported).

Proportion of samples arriving to the lab within 72 hours from collection: red (<50), yellow (50-79.99), green (80+).

DM = District Municipality; MM = Metro Municipality

Table 4. Polioviruses sequenced from acute flaccid paralysis cases and contacts from the Southern African region, 2020.

Country	Sample Received	Sabin 2	VDPV 2
Eswatini	0	0	0
Mozambique	6	0	0
Burkina Faso	104	22	75
Angola	37	11	19
Guinea	44	2	25
Lesotho	0	0	0
Malawi	3	0	0
Chad	6	0	0
Ethiopia	59	21	30
Senegal	0	0	0
Cote d'Ivoire	131	33	86
Sierra Leone	3	0	3
Mali	47	0	38
Niger	41	14	11
Democratic Republic of the Congo	325	110	195
Madagascar	0	0	0
Namibia	1	0	0
Republic of Sudan	60	5	55
Zambia	17	17	0

Environmental surveillance

A total of 101 South African environmental sewage samples was received in 2020. Four samples tested positive for Sabin poliovirus strains (Table 5). The NPEV isolation rate for environmental surveillance was 46% in 202

Table 5. Distribution of environmental samples confirmed to be positive for Sabin 1 and Sabin 3, by province, South Africa, 2020.

Province	District	Site	Poliovirus strains	Number of samples
Gauteng	Tshwane	Daspoort	Sabin 1	1
Free State	Mangaung	Sterkwater	Sabin 3	1
Gauteng	Johannesburg	Northern	Sabin 3	2

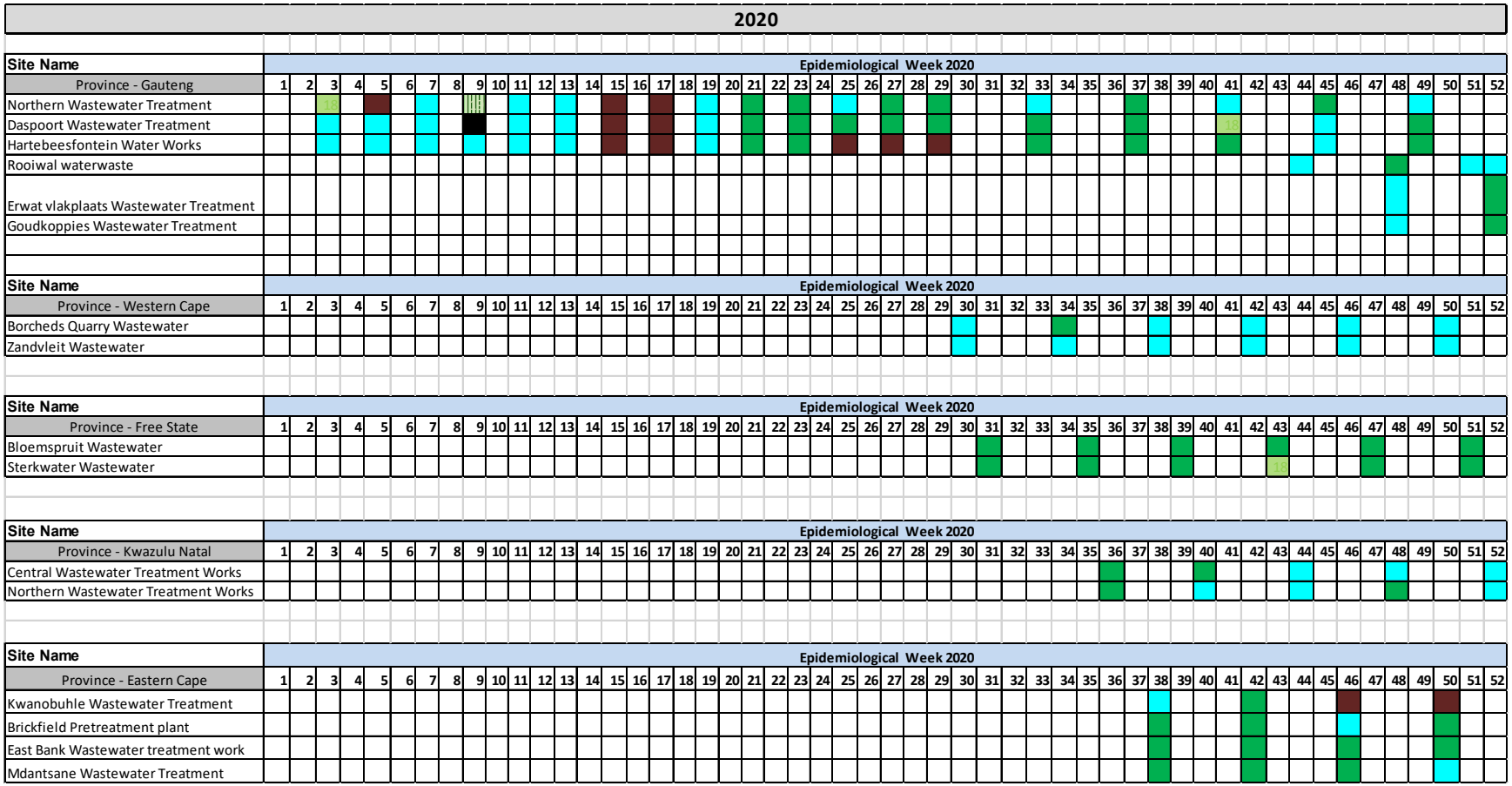

Figure 1. Dashboard of poliovirus environmental surveillance conducted in Gauteng, Western Cape, Free State, KwaZulu Natal, and Eastern Cape provinces in 2020. Light green represents Sabin strains, brown represents scheduled but not collected, blue represents non-polio enterovirus, dark green represents negative, black represents non-enterovirus, green with black lines represents Sabin and non-polio enterovirus.

Angola (Figure 2) and Mozambique (Figure 3) sent environmental sewage samples to NICD for poliovirus screening in 2020. In Angola, circulating VDPV2, Sabin poliovirus type 2 and Sabin poliovirus type 3 were detected in weeks 7, 9 and 51, respectively. In Mozambique, five environmental samples tested positive for Sabin polioviruses, three for Sabin poliovirus type 3, and two for Sabin poliovirus type 1.

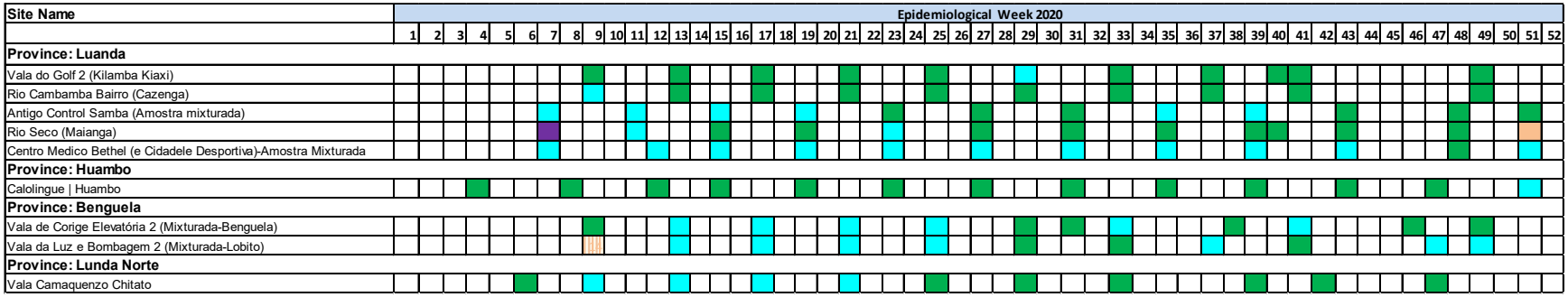

Figure 2. Dashboard of poliovirus environmental surveillance conducted in Angola in 2020. Light green represents Sabin, brown represents scheduled but not collected, blue represents non-polio enterovirus, dark green represents negative, purple represents circulating vaccine derived poliovirus type 2, white represents not scheduled, and white with brown lines represents Sabin 2.

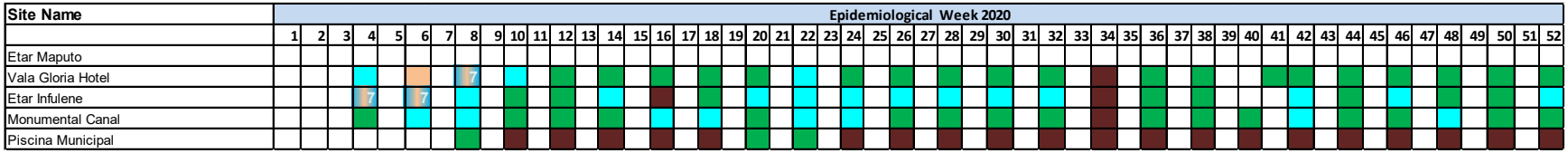

Figure 3. Dashboard of poliovirus environmental surveillance conducted in Mozambique in 2020. Light green represents Sabin, brown represents scheduled but not collected, blue represents non-polio enterovirus, dark green represents negative, blue and a brown line represents non-polio enterovirus and Sabin-like, light brown represents Sabin-like, white represents not scheduled.

Discussion

During 2020, Sabin poliovirus types 1 and/or 3 were detected from four South African AFP cases. Detection of Sabin strains from stool is usually a coincidental finding in countries using oral polio vaccines. Surprisingly few Sabin poliovirus strains were detected in the environmental sewage surveillance despite frequent isolation in the laboratory of non-polio enteroviruses from sewage samples (Figure 1). In South Africa, OPV is administered to infants at birth and six weeks of age only, therefore the increasing use of disposable nappies for infants may limit the circulation of Sabin poliovirus in the sewage system.

Since the African region was declared wild polio-free, circulating VDPV is the only form of poliovirus affecting the African region.[8] The Democratic Republic of the Congo had the most samples containing circulating VDPV type 2 (Table 4). The high number of Sabin 2 viruses detected in African countries is an indication of interventions to stop circulating VDPV type 2 outbreaks using monovalent oral poliovirus type 2 vaccine.

The prevalence of NPEV in children from low-income countries is high and the laboratory is expected to routinely isolate non-polio enterovirus from AFP cases and environmental surveillance samples.[9] The NPEV rate is not a core AFP indicator; however, it may be used as an indicator to assess the performance of laboratories to isolate enteroviruses.[10] The NPEV in AFP samples was recorded below 10% similar 3.5% in the year 2019. Few enteroviruses were isolated, likely due to restriction of movement preventing circulation of enteroviruses from person to person. The NPEV rate may be influenced by several factors, such as the season of the year, elevation, or population hygiene levels.[11] In environmental samples, the NPEV isolation rate for 2020 was 46%, compared to 87% in 2019. Although the NPEV isolation rate decreased during the COVID-19 lockdown, our environmental surveillance was capable of detecting non-polio enteroviruses which is an indication that our surveillance is sensitive to detect polioviruses.

Conclusion

Sabin 2 and circulating VDPV2 were the most prevalent poliovirus strains in the African region. While the African region has been declared wild-type polio-free, the continent still faces the challenge of circulating VDPV2 outbreaks.[2] There is an urgent need for more African countries to use nOPV2 vaccines to prevent circulating vaccine-derived poliovirus type 2 outbreaks.

As we get closer to global eradication, environmental surveillance has proven to be an advantageous tool to monitor poliovirus circulation[9] and lessons learned can be applied to environmental monitoring of other pathogens, including SARS-CoV-2.

The percentage of South African samples arriving at the laboratory within 72 hours was below the WHO target. There is an urgent need to improve the logistics of sample transportation to the laboratory within the required time. Although South Africa has reached the WHO non-polio AFP detection rate, most provinces failed to meet the South African non-polio AFP detection rate. As the Global Polio Eradication Initiative winds down and devolves to regional WHO initiatives, incorporation of national AFP surveillance targets into integrated disease surveillance will require attention.

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References

1. Khan F, Datta SD, Quddus A, Vertefeuille JF, Burns CC, Jorba J, et al. Progress toward polio eradication—worldwide, January 2016–March 2018. *Morbidity and Mortality Weekly* Report. 2018;67(18):524.
2. Leke RGF, King A, Pallansch MA, Tangermann RH, Mkanda P, Chunsuttiwat S, et al. Certifying the interruption of wild poliovirus transmission in the WHO African region on the turbulent journey to a polio-free world. *The Lancet Global Health*. 2020.
3. Bigouette JP, Wilkinson AL, Tallis G, Burns CC, Wassilak SG, Vertefeuille JF. Progress Toward Polio Eradication—Worldwide, January 2019–June 2021. *Morbidity and Mortality Weekly Report*. 2021;70(34):1129.
4. World Health Organization, Implementation of novel oral polio vaccine type 2 (nOPV2) for circulating vaccine-derived poliovirus type 2 (cVDPV2) outbreak response: technical guidance for countries. 2020.
5. World Health Organization, 2003. Guidelines for environmental surveillance of poliovirus circulation. Available at: https://polioeradication.org/wp-content/uploads/2016/07/WHO_V-B_03.03_eng.pdf (accessed: 13 October 2021).
6. Olsen SJ, Azziz-Baumgartner E, Budd AP, Brammer L, Sullivan S, Pineda RF, et al. Decreased influenza activity during the COVID-19 pandemic—United States, Australia, Chile, and South Africa, 2020. *American Journal of Transplantation*. 2020;20(12):3681-5.

7. Prabdial-Sing, N., Motaze, V., Manamela, J., McCarthy, K. and Suchard, M., 2021. Establishment of Outbreak Thresholds for Hepatitis A in South Africa Using Laboratory Surveillance, 2017–2020. *Viruses*, *13*(12), p.2470
8. Polio Global Eradication Initiative, Polio Today, www.polioeradication.org. (Access: 08 October 2021).
9. Hamisu AW, Blake IM, Sume G, Braka F, Jimoh A, Dahiru H, et al. Characterizing environmental surveillance sites in Nigeria and their sensitivity to detect poliovirus and other enteroviruses. *The Journal of infectious diseases*. 2020.
10. Raji IA, Abubakar AU, Ahmad A, Gidado S, Olorukooba AA, Lawal BB, et al. Evaluation of acute flaccid paralysis surveillance indicators in Sokoto state, Nigeria, 2012–2019: a secondary data analysis. *BMC Public Health*. 2021;21(1):1-9.
11. World Health Organization, 2004. *Polio laboratory manual, 4th ed*. World Health Organization. https://apps.who.int/iris/handle/10665/68762 (Access: 29 October 2021).

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