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Evaluation of the mpox surveillance system in Cameroon from 2018 to 2022: a laboratory cross-sectional study

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Abstract

Background Formal assessment of a surveillance system's features and its ability to achieve objectives is crucial for disease control and prevention. Since the implementation of the mpox surveillance system in Cameroon, no evaluation has been conducted.

Methods In a cross-sectional study, we assessed the performance of the mpox surveillance system in accordance with the Centers for Disease Control and Prevention (CDC) and World Health Organization (WHO) guidelines. We collected mpox surveillance data from 2018 to 2022 and conducted a survey with key stakeholders of the surveillance program. The survey results were summarized. The rates of complete reporting and mpox detection, as well as the time lag between the different stages of surveillance were analyzed using R version 4.1.

Results The mpox detection rate was 21.6% (29/134) over the five years under review. Surveillance indicators revealed that a combination of sample types, including vesicles, crust, and blood, was associated with higher case confirmation. Overall, the mpox surveillance system was effective. Weaknesses in terms of simplicity were identified. Most components of the assessed system failed to meet the timeliness and data quality goals, except for the laboratory component, which was commendable. The lack of a computerized shared database and the system's non-sustainability were a course of concern.

Conclusions Despite all identified bottlenecks in the mpox surveillance system in Cameroon, it was found to meet it stipulated goals. Recommendations are made for training on surveillance system features, particularly at the facility/field level. Therefore, there is a crucial need to globally improve the mpox surveillance system in Cameroon for better disease control.

Keywords Mpox, Surveillance, Cameroon, Surveillance system, Surveillance steps, Attributes, Disease control

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Background

Mpox previously called Monkeypox, is a re-emerging and contagious infection caused by the mpox virus (MPXV) of the genus *Orthopoxvirus* in the *Poxviridae* family [1, 2]. The MPXV primary transmission occurs through direct contact with body fluids, skin lesions of an infected animal, or indirectly via contaminated fomites. Similar contact with an infected person or infected respiratory droplets might also lead to human-to-human secondary transmission [3, 4]. In humans, the disease presents with flu-like symptoms, adenopathy, and typical skin maculopapular rashes which can be severe and potentially fatal [3, 5]. Phylogenetic studies have reported two distinct clades of MPXV: the Congo basin clade prevalent in Central Africa and the West African clade found in West Africa, known as clade I and clade II, respectively [6–8]. Clade I is considered to be more virulent with a lethality rate varying from 1 to 10% [3, 9, 10]. Mpox treatment mainly involves supportive care and few antiviral molecules including tecovirimat and brincidofovir, are used for their activities against MPXV. Cross-immunity from smallpox vaccination offers protection against MPXV infection [11–13]. Since the discontinuation of smallpox vaccination in the early 80s, herd immunity has declined, favoring the re-emergence of MPXV, as evidenced by increasing cases across various regions in Africa over the last three decades [3, 11, 14–16].

Since its discovery in 1958 in a laboratory monkey imported from Denmark [17] and a baby-boy in the Democratic Republic of Congo (DRC) in 1970 [18], and subsequent outbreaks in various African countries (DRC, Central African Republic (CAR), Gabon, Republic of the Congo, Nigeria, Ivory Coast, Morocco, Ghana, Liberia, Sierra Leone, Sudan, and Cameroon) where the virus is endemic [3, 6], MPXV has spread globally, affecting over 100 non-endemic countries in recent years [3]. Before May 2022, the virus was seldomly reported in the western hemisphere, but this was due to factors such as the exotic pet trade and international travel. The number of cases outside Africa has surged unprecedentedly recently [19–25]. As a result, in July 2022, the WHO declared it a Public Health Emergency of International Concern (PHEIC), highlighting the crucial need for epidemic preparedness, response, and global health through efficient surveillance for early detection and response to mpox cases.

Collaborative surveillance, emergency coordination, community protection, safe and scalable care, countermeasures, and research are core components of the WHO Strategic Preparedness, Readiness, and Response Plan (SPRRP) for controlling mpox [26]. As regards the main objectives of interrupt human-to-human transmission and minimize zoonotic transmission, robust surveillance systems are crucial for monitoring disease trends, informing public health policies, and achieving the primary goals of interrupting human-to-human and zoonotic transmission [27–29]. In Cameroon, mpox is a priority disease under surveillance in both the human health and zoonosis sectors. The surveillance strategy involves case-based surveillance under the Integrated Disease Surveillance and Response (IDSR) strategy implemented in 2002, with immediate notification of suspected cases. Before the implementation of mpox surveillance system, only three confirmed cases of human mpox were documented in Cameroon [30–33]. Subsequently, two epizootics occurred in captive chimpanzees in 2014 and 2016 and an additional human case was reported in 2018 [34–36]; however, many outbreaks have gone undocumented due to delays in sample collection and submission between 2018 and 2022 [33, 34]. Despite efforts to enhance surveillance following global outbreaks, MPXV cases in Cameroon remain underreported and outbreaks are often detected late [34, 35]. The exact burden of mpox in Cameroon is unknown, highlighting the need for formal evaluation of the surveillance system to ensure its effectiveness and identify areas for improvement. The mpox surveillance system has not been assessed since its establishment in Cameroon. This study aimed to assess the features of the mpox surveillance system in Cameroon, evaluate its performance, identify bottlenecks, and suggest improvements.

Methods

Study design and setting

We conducted a cross-sectional study based on retrospective mpox data from 2018 to 2022 and a survey among key stakeholders of the mpox surveillance system in Cameroon to collect prospective data. Cameroon is a central African country divided into 10 regions, and 58 divisions further split into 360 subdivisions, with 205 health districts and 1 800 districts areas as the smallest administrative health units, for approximately 27 million inhabitants. Cameroon's public health system operates on a hierarchical pyramidal tripartite structure at national, regional, and district levels. We surveyed mpox surveillance indicators based on laboratory and field epidemiological surveillance data.

Mpox surveillance system in cameroon

In Cameroon, despite existing laws for preventing and controlling zoonotic diseases, the measures to be taken in cases of suspicion and/or confirmation of a case of mpox are not well documented. However, there is a national mpox surveillance system established by the Ministry of Health (MoH) in 2002, which has been extensively improved in the last two years under the "One Health" approach led by the National Program for the Fighting Against Emerging and Re-emerging Zoonosis (PNLER). Mpox is among the ten priority notifiable

zoonotic diseases in Cameroon, and surveillance is coordinated by the Department for the Control of Disease, Epidemics and Pandemics (DLMEP) of the MoH. In December 2022, the MoH drafted national surveillance guidelines for mpox, following a "One Health" approach, involving key sectors. Additionally, PNLZER has led the development of a multisectoral mpox strategic response plan. The preparedness and response strategy for mpox outbreaks in Cameroon is underpinned by multisectoral coordination, early detection, laboratory diagnosis, timely investigation and follow-up of all contacts, case management, infection prevention and control, risk communication, and community engagement.

Mpox symptoms mimic those of other eruptive fevers but have some distinct features. The mpox national case definition, adapted from international recommendations for mpox from WHO and the CDC, outlines mpox suspected case as any person with one or several clinical signs including headache, asthenia, adenopathy, myalgia, fever, and vesicular maculopapular rashes that gradually spread to different body parts, including the palms and soles of the feet. A confirmed case involves laboratory confirmation through PCR testing, while a probable case lacks virological confirmation but has an epidemiological link to another probable or confirmed case.

In Cameroon, suspected or probable cases are identified by community health workers or clinicians and reported to the health district service, which in turn reports to the decentralized regional services of the MoH, namely, the Regional Centers for Epidemic Prevention and Control (CERPLE). The CERPLE notifies the DLMEP, which instructs a preliminary investigation, and sample and epidemiological data collection if cases are suspected or clinically confirmed. A local Rapid Response and Investigation Team (RRIT) composed of an epidemiologist, a clinician, a lab-technician, a veterinarian, a wildlife specialist, an environmentalist, a psychological care officer, and a communication officer is set up for data collection and response. The national surveillance strategy recommends collecting appropriate samples of pustular vesicle swab and/or crust samples, accompanied by a 5 ml blood sample, transported under a reverse-cold chain triple packaging system to the Centre Pasteur du Cameroun (CPC), which is the national reference laboratory for the diagnosis of mpox in Cameroon (Fig. 1). Upon arrival at the CPC, PCR testing and differential diagnosis are completed, and the results are reported to the MoH within 24 h. In the meantime, suspected patients are isolated in the nearest healthcare center where they receive supportive treatment until the availability of laboratory results confirming or negating potential infection. The laboratory results from the CPC are shared with the DLMEP and other health authorities at different levels. The National Public Health Observatory (NPHO) notifies the WHO in case of a public health emergency threat, following the International Health Regulation (IHR) guidelines, Annex 11.

Mpox suspected cases are identified by community health workers or clinicians under the coordination of the Health District which notify to the Department for the Control of Disease, Epidemics and Pandemics (DLMEP) and the Regional Centers for Epidemic Prevention and Control (CERPLE), which will set up a Rapid Response and Investigation Team (RRIT) responsible for collecting epidemiological data and samples. The RRIT will provide feedback to the CERPLE and the Health district regarding sample collection. The latter will handle sample packaging, the cold chain and shipment. The collected samples will be transported to Centre Pasteur du Cameroun (CPC), the national reference laboratory for Mpox

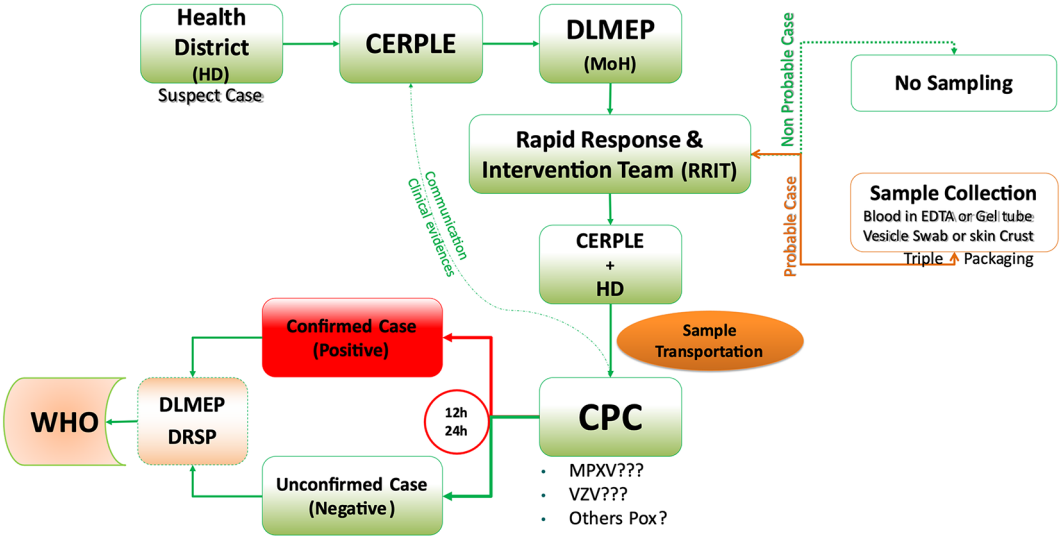


Fig. 1 Mpox surveillance system in Cameroon

diagnosis. CPC is responsible for processing received samples and providing results in 24 h to the DLMEP, which will fast-track final results to its decentralized services (DRSP, regional department of public health) and to the WHO.

Evaluation scope of the Mpox surveillance system in Cameroon

The Mpox surveillance system in Cameroon was evaluated based on the Updated Guidelines for Evaluating a Public Health Surveillance System of the CDC, Atlanta, United States of America [37]. CDC guidelines define the main features of an effective and efficient surveillance system. Using the performance indicators recommended in the revised WHO guidelines on mpox surveillance and laboratory testing, we compared the results of our evaluation of the surveillance system to ascertain the system's overall reliability and effectiveness [29, 38]. We measured key attributes of the surveillance system through a survey and an analysis of the mpox surveillance database (Table 1).

Data collection, management and analysis

This study involved analyzing quantitative and qualitative data related to Mpox surveillance in Cameroon.

Quantitative data analysis was conducted from April 1–15, 2023, using retrospective anonymized surveillance data from 2018 to 2022 in R version 4.1 [39]. Cases tested for mpox during this period, with recorded epidemiological information were considered (see supplementary file 1). We excluded data from duplicate cases and those lacking laboratory results. Quantitative attributes were compared to the outcome of MPXV diagnostic PCR using a Fischer-test. Logistic regression was used to determine whether quantitative measures attributes were associated with MPXV infection and to estimate odds ratios (ORs) at 95% confidence intervals (95% CIs). ORs were presented as crude values in the univariate analysis. Variables were considered statistically significant for p values <0.05 and marginally significant for p values <0.06.

We calculated the mpox positive predictive value (PPV) by dividing the total number of mpox PCR-confirmed cases by the total number of suspected mpox cases. We sorted the different types of samples collected and compared their frequencies with the final test results. To evaluate the mpox surveillance system timeliness, we computed facility/field and laboratory turnaround times and assessed indicators such as disease onset and final diagnostic turnaround times.

Qualitative data collection occurred from February 6 to March 10, 2023, through interviews with mpox surveillance stakeholders at different levels in Cameroon using a standardized hard-copy questionnaire (see supplementary file 2). They included community health workers, clinicians and surveillance focal points at the district level; CERPLE team leaders in at-risk areas at the regional level; practitioners and heads of the reference laboratory and DLMEP coordinators for mpox at the national level. Using both closed- and open-ended questions, the stakeholders provided sociodemographic information and insights into the key attributes of the mpox surveillance system (see supplementary file 2). Prior to data collection, we provided information sheets to the participating stakeholders and obtained oral informed consent before the interviews. Stakeholders' replies were treated in Microsoft Excel and the usefulness and simplicity of the mpox surveillance system were assessed.

Table 1 Measurement of the attributes of the Mpox surveillance system

Attributes	Measurements	Data source	
Quantitative		**Mpox database**	**Cross-sectional survey**
Positive predictive value	Proportion of PCR-confirmed Mpox cases in relation to the total number of reported suspected cases tested for Mpox infection.	**Yes**	
Sample adequacy	Sorting the different type of sample collected and used for Mpox diagnostic and comparison with indicated appropriate sample for Mpox diagnostic	**Yes**	
Timeliness	Turnaround times for disease onset, health facility/field intervention, and laboratory analyses (in days)	**Yes**	
Data quality	Proportion of fully completed case report forms in the Mpox database; A complete form is defined a fully completed form containing demographic information such as date of birth, sex, name of health facility, name of care unit; clinical information such as date of onset of disease; epidemiological information such as name of district, name of region; and laboratory information such as date of specimen collection, laboratory reference number, date of test registration, date of test result review and any other clinical and epidemiological information requested.	**Yes**	
Qualitative			
Usefulness	Assessment of the system's ability to achieves its objectives		**Yes**
Simplicity	Assessment of stakeholder opinions on Mpox case definition, notification process and system tools		**Yes**
	Indirect evaluation by verifying the thoroughness of collected data using surveillance tools	**Yes**	

Results

From 2018 to 2022, 149 suspected mpox cases were identified in Cameroon (Fig. 2). Demographic and geographic information of the cases are reported elsewhere [33]. After excluding 10.1% (15/149) of the records composed of results occurring in duplicate and those without mpox test results, 89.9% (134/149) of the records were analyzed. The study included, 72 (53.7%) men, 61 (45.5%) women, and one (0,7%) sample with missing gender information. Of the 134 samples considered, 62.7% (84/134) were collected and tested in 2022 (Fig. 2).

Quantitative attributes

The positive predictive value (PPV) of the MPXV generic PCR assay was 21.6% (29/134), varying from 7.7% (1/13) in 2018 to 100.0% (1/1) in 2019. In 2020, it was 17.2% (5/29), 71.4% (5/7) in 2021, and 20.2% (17/84) in 2022. Considering the 5-year overall PPV, the year 2022 displayed the highest positive rate, with 58.6% (17/29) of laboratory-confirmed cases. Overall, there is a discrepancy in the reporting of mpox cases in Cameroon and the year 2022 in particular shows an increase in confirmation and reporting rates of more than 300% compared to the previous two years during which the largest number of mpox cases were reported in Cameroon (Fig. 3).

Sample adequacy

A total of 50 specimens (37.3%) submitted for laboratory testing were blood specimens, 11 (8.2%) were unique vesicular swabs, 4 (3.0%) were exclusive crust samples, and 68 (50.7%) were a mixed combination of two or three (rarely) different types of samples (Table 2). Considering the total of 29 MPXV-confirmed cases over the monitored period, MPXV cases were mostly confirmed based on appropriate samples of vesicular fluids ($n=4$, 13.8%) or mixed sample sets ($n=19$, 65.5%) rather than blood samples ($n=6$, 20.7%) (Table 2). The odds ratio results showed that there were three and four times greater chances of obtaining a positive diagnosis based on mixed sample sets and vesicle swab samples, respectively.

Timeliness

We have outlined timeliness here as the time between disease onset, sample collection, and laboratory turnaround time. Surveillance indicators (Table 2) revealed a median time of 15.81 days from disease onset to sample collection (range: 2–92 days; interquartile range (IQR): 4–15.5 days), and 3.93 days from collection to laboratory delivery, ranging from <1 day to up to 35 days (IQR: 1–4 days). The median time for completing MPXV generic PCR testing along with differential varicella zoster virus (VZV) PCR diagnostic results was approximately a day, with results available within 24 h to 5 days (IQR: 0–1 days). The median turnaround time from disease onset to laboratory results was 11 days (range: 3–96 days; IQR: 7–16.5 days). This timeframe did not differ according to the patient's status (confirmed or negated) (Table 2).

Data quality

The mpox surveillance system in Cameroon involves field actors, the regional level, the laboratory, and the national level, with data managed in a pyramid structure. Currently, there is no database sharing among stakeholders, leading to each entity creating its own database by cross-referencing information from various surveillance tools. The database used to assess data quality was the one generated in the laboratory based on records collected in the field and cross-checked with those in the field and at the

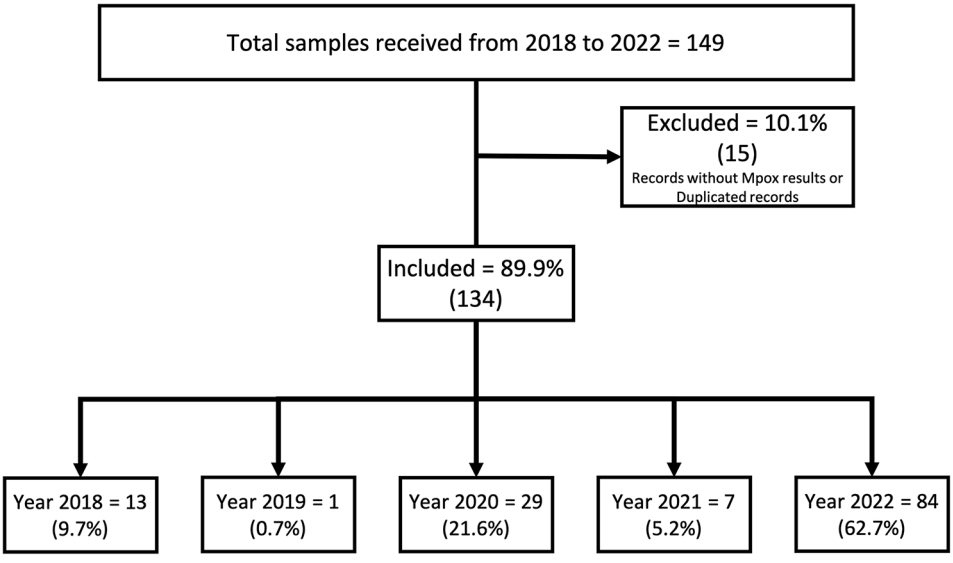
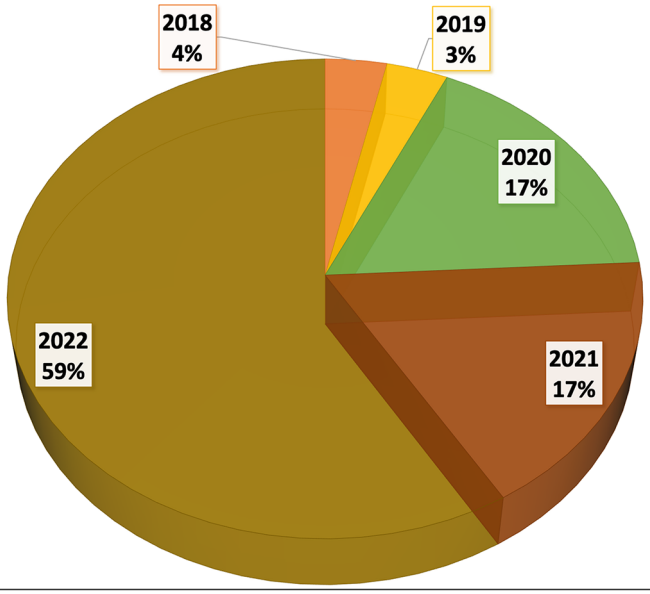


Fig. 2 Number of samples tested for Mpox disease in Cameroon, 2018–2022



Years	2018	2019	2020	2021	2022
Annual detection of Mpox in suspect cases	1	1	5	5	17
Annual reported Mpox suspect cases	13	1	29	7	84
Mpox Proportion	7.7	100.0	17.2	71.4	20.2

Fig. 3 Mpox notification and confirmation over 5-year period (2018–2022) of surveillance in Cameroon. The numbers on the chart indicate the proportion of positive mpox cases per year over the total number of mpox confirmed cases in Cameroon for the five years under survey. The associated table display the mpox predictive values we calculated per year

national level (see supplementary file 1). The data quality revealed that complete information was available for only 56% (75/134) of the epidemiological forms in the database (Table 3). However, the quality of the laboratory data was good, with over 97% of the samples having complete traceable information. Participating stakeholders at the district, regional and national levels reported delays and incomplete monitoring tools from facilities/field, preventing accurate data analysis.

Adequacy performance indicators

Evaluation of the performance indicators for the adequacy of the Mpox surveillance system in Cameroon showed that the system met the evaluated objectives, by confirming or ruling out the presence of mpox. An exception was observed in 2019, when only one mpox case was detected and confirmed (Figs. 2 and 3).

Qualitative attributes

Usefulness

The survey results and analysis of the surveillance data revealed that the mpox surveillance system in Cameroon successfully achieved its objectives (Table 4). National-level stakeholders from the DLMEP often release mpox surveillance data in real-time notifications and monthly situational reports of suspected cases. Data analysis provided insights into regional mpox surveillance, with approximately 90% of cases concentrated in the Southwest, Northwest, and Centre regions of Cameroon, aiding in identifying populations and areas at risk. Furthermore, national level participants mentioned that there were plans to study immunity gaps in at-risk populations in Cameroon through systematic blood sample collection from confirmed cases. However, decisions or policies derived from the Mpox surveillance data were not readily accessible to facility- or field-level participants who claimed their unawareness.

Simplicity

In Cameroon, specific mpox case definitions have been established. In line with established definitions, data were collected in the field using a multitool approach, including notification, case investigation, line listing, and laboratory forms. However, there is no electronic database or application for this system.

Facility/field-, district-, and regional-level stakeholders found the surveillance system complex because of delayed feedback on cases and centralized investigations around confirmed cases. Sharing surveillance information is cumbersome without a computerized system for mpox surveillance and limited Internet connectivity at the facilities "they said". They rely on traditional hard-copy forms and personal resources (phones, WhatsApp, etc.) to interact with stakeholders. It has been pointed out that the facility/field level usually transmits incomplete information to other stakeholders. The majority of

Table 2 Surveillance indicators in mpox suspected and confirmed cases in Cameroon from 2018 to 2022

Cases Characteristics	MPXV RT-PCR Result		Crude OR (95% CI)	*p* value
	Positive (%) *n* = 29 (21.64%)	Negative *n* = 105 (78.36%)	Total 134 (100%)	
Sample used for Laboratory testing				
Blood	6 (20.69)	44.00	1	**0.050**
Vesicle Swab	4 (13.79)	7.00	4.19 (0.94–18.70)	
Skin Crusts	0 (0.00)	4.00	0 (0-∞)	
Mixed Samples	19 (65.52)	49.00	2.84 (1.04–7.76)	
Missing	0	1		
Time between Disease onset and sampling (days)				
Min.	1.00	1.00	1.00	0.3928
1st quartile	5.00	3.00	4.00	
Median	7.00	8.00	7.00	
Mean	8.86	18.49	15.81	
3rd quartile	10.75	26.00	15.50	
Max.	31.00	92.00	92.00	
Missing	7.00	48.00	58.00	
Time between sampling and delivery to the laboratory (days)				
Min.	0.00	0.00	0.00	0.8357
1st quartile	2.00	1.00	1.00	
Median	2.00	3.00	3.00	
Mean	3.59	4.02	3.93	
3rd quartile	3.00	4.00	4.00	
Max.	32.00	35.00	35.00	
Missing	0.00	1.00	4.00	
Time between Receipt at the laboratory and result availability (days)				
Min.	0.00	0.00	0.00	0.5505
1st quartile	0.00	0.00	0.00	
Median	0.25	1.00	1.00	
Mean	1.27	1.08	1.13	
3rd quartile	1.75	1.00	1.00	
Max.	4.00	5.00	5.00	
Missing	3.00	27.00	27.00	
Time between Disease onset and Result availability (hrs)				
Min.	4.00	3.00	3.00	0.6529
1st quartile	7.75	7.00	7.00	
Median	11.50	11.00	11.00	
Mean	11.83	21.58	18.79	
3rd quartile	14.00	31.00	16.50	
Max.	32.00	96.00	96.00	
Missing	11	60	74	

OR: Odd Ratio; CI: Confident Interval; hrs: hours

stakeholders in the field do not master the typical definition of an mpox case but rather an 'extended' ore community case definition as it has been largely widespread and extended to 'any suspect rash, a sample should be taken' to ensure that cases are not missed. This broadened case definition helped rule out another concern raised about mistaking mpox for other eruptive diseases, such as chickenpox. Stakeholders also raised concerns about diagnosis in a centralized laboratory, appropriate sample choice, and timely investigations around confirmed cases. Limited infrastructure (communication and transportation means) hinders the identification of all suspected cases of mpox, sample collection and transportation and investigation, impacting early case detection, particularly in remote areas where most suspected cases of mpox have occurred. Under-detection of cases was also linked to limited funds, as one participant stated, "It's not easy to identify all mpox cases as we currently rely on partner support". Mpox surveillance in Cameroon is not sustainable and is currently supported by partners. Most often, when the support stops, the surveillance also goes on standby.

Table 3 Data quality of the mpox surveillance system, Cameroon, from 2018 to 2022

Variables ($n = 134$)	Number of records with complete information (%)	Number of records without complete information (%)
Overall data quality (2018–2022)		
Complete records	75 (56.0)	59 (44.0)
Data quality per year		
2018	6 (46.2)	7 (53.8)
2019	0 (00.0)	1 (100.0)
2020	4 (13.8)	25 (86.2)
2021	2 (28.6)	5 (71.4)
2022	63 (75.0)	21 (25.0)
Clinical characteristics		
Epidemiological number	9 (6.7)	125 (93.3)
Region's name	134 (100)	0 (00.0)
Health district Name	134 (100)	0 (00.0)
Village name	134 (100)	0 (00.0)
Facility name	134 (100)	0 (00.0)
Case's date of birth	132 (98.5)	2 (1.5)
Sex	133 (99.3)	1 (0.7)
Date sample collection	134 (100)	0 (00.0)
Date disease onset	78 (58.2)	56 (41.8)
Global disease symptoms	110 (82.1)	24 (17.9)
Rashes assessment	46 (34.3)	88 (65.7)
Laboratory characteristics		
Test laboratory number	134 (100)	0 (00.0)
Laboratory reference number	134 (100)	0 (00.0)
Test registration date	134 (100)	0 (00.0)
Date sample reception	134 (100)	0 (00.0)
Test week	124 (92.5)	10 (7.5)
Test month	124 (92.5)	10 (7.5)
Test year	134 (100)	0 (00.0)
Sample type	133 (99.3)	1 (0.7)
Results review date	124 (92.5)	10 (7.5)
Risk factors characteristics		
Travel history	116 (86.6)	18 (13.4)
Forest activity	28 (20.9)	106 (79.1)
Contact with wild animal	109 (81.3)	25 (18.7)
Contact with sick person	115 (85.8)	19 (14.2)

Table 4 Objectives of the mpox surveillance system in Cameroon, 2018 to 2022

Objectives	Achieved
Estimating the primary epidemiological characteristics of mpox (incidence, prevalence and trends) over time	Yes
Spot mpox Outbreaks	Yes
Identify population groups and areas at risk from mpox	Yes
Provide system users with information on mpox prevention and control strategies.	Yes

The national-level stakeholders (DLMEP) were unsure about the system's user-friendliness. They affirmed disseminating summaries of surveillance data to the regional levels in real-time and through monthly reports. They raised challenges in sharing mpox surveillance data with other stakeholders due to the lack of specific surveillance tools and stock shortages in the field. They stressed the need for an electronic notification system for real-time access to information. There is good hope for case-based electronic surveillance thanks to the information system still under development in Cameroon, the DHIS-2 (District Health Information System). Another major challenge identified at the national-level was the lack of an integrated sample transport system currently dependent on partner support and covering only the journey from the regional-level to the reference laboratory, thus limiting the timely transportation/referral of samples. Inadequate training for health professionals in surveillance and case management was also mentioned. Furthermore, case management is payable, and supportive treatments are not sent to health facilities to facilitate patient management. Finally, national-level shareholders mentioned that the lack of sustainable funding for mpox

surveillance affects multisectoral investigations and epidemic response evaluations.

Discussion

This study was performed to assess the mpox surveillance system in Cameroon over a 5-year period (2018–2022). Since the eradication of smallpox in Cameroon in 1970, the surveillance of other potential orthopox infections able to induce smallpox-like illnesses has been quite poor in the country [40]. In 1979, the first case of mpox was identified in Cameroon, followed by the second case in 1980, and the third case in 1990 [30–32]. It was not until 30 years later that a report in 2018 highlighted a re-emergence of human cases of MPXV in Cameroon, resulting in four documented cases of mpox in the country [34]. Between 2018 and 2022, there were 29 laboratory-confirmed cases of 134 suspected cases, with an unprecedented outbreak in 2022 confirming 17 suspected cases [33]. The recent increase in confirmed cases in Cameroon is likely due to a strengthened surveillance system that has enhanced awareness among stakeholders and community workers in recent years, particularly in 2022. The 2022 global epidemic has considerably contributed to increased awareness among stakeholders and community workers from the central to the operational levels of the public health system of Cameroon [33]. The same trend was observed in CAR, where continuous reporting of cases was observed only when surveillance became more active and systematic [16]. However, there are still areas of the surveillance system in Cameroon that need improvement to scale up the detection rate in the country to meet those of neighboring countries such as CAR and DRC, which share the same ecogeographic and cultural settings [16, 41].

Mpox surveillance in Cameroon has substantially improved during the last two years with the adoption and implementation of specific guidelines for disease surveillance (systematic investigation and reporting), management, and control. Evaluation of the mpox surveillance system in Cameroon revealed its effectiveness but complexity, with a low PPV in the years under review. Indeed despite a case definition which is sensitive enough to pick many other illnesses, the system identified less than two hundred cases in five years, thus highlighting marked underreporting in Cameroon. The low PPV observed could partly be due to the incomplete implementation and dissemination of case definitions, national control plans, and operational guidelines for surveillance and response to Mpox in Cameroon. Surveillance stakeholders are yet to familiarize themselves with the recently finalized integrated guidelines, and not all standard operating procedures have been fully mastered; thus, errors in sample collection and delays in sample treatment are imminent. This may result in depicting the burden of mpox in Cameroon, missing outbreaks, and underestimating the incidence and prevalence.

Surveillance indicators revealed that most mpox cases were confirmed based on recommended vesicle swabs or crust samples, while a considerable fraction of suspected cases, for which only blood samples were available tested negative. Some cases may have been false negatives due to the transient nature of MPXV viremia, as blood samples are known to be less sensitive than vesicular swabs or crust samples [42]. In addition, the detection of mpox cases in Cameroon could have been negatively impacted by the long time elapsed between the onset of the disease and the collection of samples for a confirmatory diagnosis, as well as the time required to transfer these samples to the laboratory. The surveillance system was efficient in its laboratory components, with a commendably rapid median turnaround time of 24 h. Conversely, when considering the systems' facility components, a higher median timeliness of 3 days, with 75% of the samples reaching the laboratory in approximately 4 days. Regarding the onset timeliness, we noticed a very high median time of seven days between disease onset and sampling. The overall timeliness between disease onset and final diagnosis was 11 days, with 75% of the patients diagnosed over two weeks. As in most endemic countries, mpox in Cameroon mainly occurs in remote forested rural areas where health facilities are usually not available and patients have to travel hundreds of miles for healthcare services, leading to delays in detection and management by the surveillance system [10, 11, 16, 41, 43–46]. The transfer of samples to the reference laboratory (CPC) in the city of Yaoundé, located over 600 miles from high-risk regions, has contributed to the underreporting and underdiagnoses of mpox in Cameroon. The poor timeliness observed at the facility level mirrors a general situation of under-information on the mpox surveillance system in these facilities. The surveillance system is mainly laboratory-based; thus, improving training and awareness among laboratory and healthcare facility staff regarding the urgency to promptly confirm potential cases of mpox is essential for enhancing surveillance efficiency and timeliness at the facility level. As mentioned by national-level stakeholders, logistical challenges such as sample transportation might have impacted timeliness at the facility level. More structured studies should be conducted to find additional solutions capable of improving timeliness at the facility level and avoiding delays in mpox outbreak detection. Globally, we deplore the lack of formal WHO standards for mpox monitoring to effectively comment on our results. For example, the WHO defines the desired turnaround times for rubella surveillance as at least 80% of samples collected from the field arriving at the laboratory within three days, and at least 80% of the test results are disseminated to the national

level from the laboratory within seven days of receipt of samples [47, 48]. We did not find any such standards for mpox.

Similar to poor timeliness at the facility level, poor data quality was noted in the mpox surveillance database, particularly for data collected at the facility-level. Healthcare facilities frequently provide incomplete monitoring tools to other levels of the surveillance system because of insufficient training and awareness among facility-level healthcare workers. In addition, the lack of an electronic shared database (harmonization) contributes to the data quality issues common in Cameroon's surveillance systems. Unawareness, a lack of training to complete surveillance tools among healthcare workers, and reliance on paper-based systems have been reported as the main culprits [48–50]. Evaluation of the mpox surveillance system revealed the commendable quality of the data related to the laboratory component. This is not surprising, as laboratory stakeholders have a better understanding of the surveillance system than other stakeholders, especially those at lower levels. Setting up a computerized shared database with mandatory variables and different access levels will improve the quality of data collected at the facility level.

Assessing the usefulness of the mpox surveillance system revealed that the system can meet its primary stipulated goal, as it generates useful epidemiological information and guidance for preparedness and response in Cameroon [33, 34]. However, stakeholders at the district and facility levels are not aware of the system's importance and decision-making based on data collection, highlighting the poor communication between the national and decentralized levels. Indeed, the relatively limited number of confirmed cases and delays at the facility level are worrisome and could jeopardize the system's objectives in terms of inaccurate prevalence, incidence, and sub-detection of outbreaks. Despite the identified challenges, we expect the PPV and timeliness performance attributes to improve with time, given strides made (guidelines drafted). We should mention, nevertheless, that the data in our possession did not allow us to assess all the contours of the mpox surveillance system in Cameroon, as we were unable to capture results concerning the system's flexibility, acceptability, sensitivity, representativeness and stability.

This study revealed that stakeholders at all three levels of the mpox surveillance system did not find the system simple and sustainable, relying on laboratory components. Stakeholders are less involved during periods of lull and have difficulty reactivating in a timely manner, especially those at the district- and facility-levels. These observations led us to conclude that the mpox surveillance system in Cameroon was not user-friendly due to the nonmastery of the typical definitions of mpox cases, unclear data collection procedures and sharing, and high timeliness (facility level). The system's expanded case definition incorporating chickenpox may lead to cases being overlooked. Feedback from national to lower levels regarding confirmed and invalidated mpox cases is sometimes delayed, hindering stakeholder's commitment and timely reporting. Therefore we stress the importance of specific training on different surveillance system features to allow optimal operation. Overall, the limitation of this study was the inability to assess the system using formal WHO standards for mpox, as we were unable to find them.

Conclusion

This study describes a useful mpox surveillance system in Cameroon. However, the identification of several gaps, such as the lack of a computerized shared database system, exposes the system to data quality issues. Overall, in view of the aforementioned operational issues, we can conclude that the system is not simple and lead to marked underreporting in the country. The different gaps identified in mpox surveillance in Cameroon could serve as lessons for public health authorities to strengthen epidemic preparedness and response activities in the country. These data are also of great interest for the design, optimization and evaluation of public interventions aimed at monitoring and controlling Mpox infections in Cameroon and other countries with similar epidemiological settings in Africa.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions

Data and samples from the surveillance system survey were collected by DDD, CB, LE, MMMM and PJAA. The field investigations as well as diagnostic and research activities were coordinated by CB, LE, IMEN, GDE and MGWY. Molecular laboratory analyses were performed by GDE and MGWYY and supervised by DDD, SIE, MK, and RN. DDD, CB., LE, ED, and AGME coordinated the field work and provided stakeholders's survey data. The data were analyzed by DDD and CB. The manuscript was drafted by DDD., CB, LE, MMMM and RN. The final manuscript has been revised and approved by all the authors.

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Data availability
The datasets generated and/or analyzed during the current study are not publicly available due to the confidentiality of mpox data from the National Laboratory Surveillance in Cameroon, but are available from the corresponding author upon reasonable request and with the permission of the General Director of the Centre Pasteur in Cameroon.

Declarations

Ethics approval and consent to participate
Sample collection and laboratory analyses were conducted within the framework of the national surveillance program. Based on the Cameroon surveillance system, written or oral informed consent was obtained from all suspected cases and participating stakeholders after detailed information and explanations of the sampling purpose were provided. Informed consent for children was obtained from their parents or guardians. The study was approved by the National Ethics Committee of Health Sciences Research No 2023/02/1519/CE/CNERSH/SP and the Ministry of Public Health Research Administrative Authorization No D30-692/AAR/MINSANTE/SG/DROS, in Cameroon.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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