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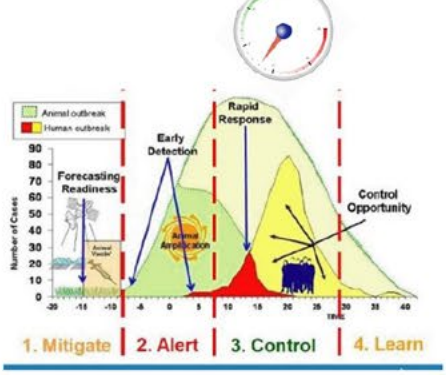
The Pan African Medical Journal

WHO Response to Disease Outbreaks in Liberia: Lessons learned from the 2014 - 2015 Ebola Virus Disease Outbreak



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The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of AFENET and WHO

This special issue of the Pan African Medical Journal documents the successful application of lesson learnt from response to the Ebola virus disease outbreak in Liberia and identifies some best practices that could be applied to other disease prevention, control and elimination programmes with similar success. The papers, written by those who were actively engaged in response to epidemics in Liberia, cover critical topics in from preparedness and response to disease outbreaks, strengthening surveillance systems and integration as well as strengthening health workforce post Ebola virus disease outbreak. The comprehensive analysis of the success stories made in disease control and epidemic response in Liberia with clear discussion of accompanying challenges presented in this special edition is extremely useful and timely. The articles carefully chart the successes in turning tragedy to gains!

Guest editors: **Ibrahima-Soce Fall (Regional Emergency Director, WHO Regional Office for Africa), Joseph C Okeibunor (Regional Social Scientist, WHO Regional Office for Africa), Alex Gasasira (WHO Representative, Liberia)**

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Ebola virus disease outbreak in Liberia: application of lessons learnt to disease surveillance and control

Ibrahima Socé Fall[1,&]

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Editorial

The outbreak of Ebola virus infection in West Africa countries, including Liberia, was the largest on record in terms of the unprecedented number of reported cases (n= 28,616), out of which 15,227 were confirmed and 11,310 deaths in Guinea, Liberia, and Sierra Leone and its' rapid transmission in dense urban populations [1]. An additional 36 cases and 15 deaths occurred in Italy, Mali, Nigeria, Senegal, Spain, United Kingdoms and United States [2]. With an estimated mortality rate at around 70%, including massive death tolls in health care workers, the epidemic undermined the hitherto fragile health-care systems and presented public health challenges that have never been encountered previously and which were further constrained with the absence of treatment and vaccination options.

Liberia was most hit by the outbreak given its fragile health system. Before the outbreak of the Ebola epidemic, Liberia struggled with a very weak health system that was devastated and weakened by a protracted civil war. It had just 50 doctors for its 4.3 million population with poor capacity to respond to an epidemic of that magnitude [3]. The Ministry of Health, with support from WHO, led the response to stop the outbreak and together with partners, mobilized both human and material resources to end the outbreak in 2015.

By the end of the outbreak a total of 4810 deaths were recorded out of 10678 confirmed cases in Liberia [2]. The epidemic had severe and devastating impacts on the health system of Liberia, including health workforce and supply chain. It stalled progress across the health sector, including progress towards achieving the MDGs. It caused a deceleration of progress in reducing mortality due in part to the deaths resulting from Ebola directly. Similar deceleration in the mortality rate due to malaria could be attributed to the disruption to malaria treatment interventions [4]. Similarly, in 2014, DTP3 coverage dropped in Liberia from 76% in 2013 to 50% in 2014 [5]. A 50% reduction in access to healthcare services during the Ebola outbreak was estimated and this exacerbated malaria, HIV/AIDS and tuberculosis mortality rates [5]. Other services affected included limited access to Caesarian sections and clinic attendance of under-5 children, with a likelihood of a resultant high morbidity and mortality.

However, a number of lessons were learnt in the process of responding to the outbreak. Some of these lessons have been deployed to strengthening the health system in Liberia and preparing it to respond not only to Ebola outbreak but the outbreak of any epidemic prone diseases. These lessons have actually been successfully applied to enhanced disease

Editorial

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However, a number of lessons were learnt in the process of responding to the outbreak. Some of these lessons have been deployed to strengthening the health system in Liberia and preparing it to respond not only to Ebola outbreak but the outbreak of any epidemic prone diseases. These lessons have actually been successfully applied to enhanced disease surveillance and response in Liberia. Other important areas where they have been applied include response to meningococcal disease cluster in Foya district, Lofa County, Liberia January to February 2018; risk Communication during disease outbreak response in post-Ebola Liberia: experiences in Sinoe and Grand Kru Counties; as well as detecting and responding to recurrent measles outbreak in Liberia post Ebola-Epidemic 2016-2017 among others.

This special issue of the Pan African Medical Journal documents the successful application of lesson learnt from response to the Ebola virus disease outbreak in Liberia and identifies some best practices that could be applied to other disease prevention, control and elimination programmes with similar success. The papers, written by those who were actively engaged in response to epidemics in Liberia, cover critical topics in from preparedness and response to disease outbreaks, strengthening surveillance systems and integration as well as strengthening health workforce post Ebola virus disease outbreak. The comprehensive analysis of the success stories made in disease control and epidemic response in Liberia with clear discussion of accompanying challenges presented in this special edition is extremely useful and timely. The articles carefully chart the successes in turning tragedy to gains!

Competing interests

All the authors declare no competing interest.

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PanAfrican Medical Journal

Research

Strengthening acute flaccid paralysis surveillance post Ebola virus disease outbreak 2015 - 2017: the Liberia experience

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This article is published as part of the supplement **"WHO Response to Disease Outbreaks in Liberia: Lessons learnt from the 2014 - 2015 Ebola Virus Disease Outbreak"** sponsored by World Health Emergencies, WHO/AFRO

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Abstract

Introduction: Liberia remains at high risk of poliovirus outbreaks due to importation. The country maintained certification level acute flaccid paralysis (AFP) surveillance indicators each year until 2014 due to Ebola outbreak. During this time, there was a significant drop in non-polio AFP rate to (1.2/100,000 population under 15 years) in 2015 from 2.9/100, 000 population in 2013, due to a variety of reasons including suspension on shipment of acute flaccid paralysis stool specimen to the polio regional lab in Abidjan, refocusing of surveillance officers attention solely on Ebola virus disease (EVD) surveillance, inactivation of national polio expert committee (NPEC) and National Certification Committee (NCC). The Ministry of Health (MOH) supported by partners worked to restore AFP surveillance post EVD outbreak and ensure that Liberia maintains its polio free certification.

Methods: we conducted a desk review to summarize key activities conducted to restore acute flaccid paralysis (AFP) surveillance based on World Health Organization (WHO) AFP surveillance guidelines for Africa region. We also reviewed AFP surveillance indicators and introduction of new technologies. Data sources were from program reports, scientific and gray literature, AFP database, auto visual AFP detection and reporting (AVADAR) and ONA Servers. Data analysis was done using Microsoft excel and access spread sheets, ONA software and Geographic Information System (Arc GIS).

Results: AFP surveillance indicators improved with a rebound of non-polio AFP rate (NPAFP) rate from 1.2/100, 000 population under 15 years in 2015 to 4.3 in 2017. The stool adequacy rate at the national level also improved from 79% in 2016 to 82% in 2017, meeting the global target. The percentage of counties meeting the two critical AFP surveillance indicators NPAFP rate and stool adequacy improved from 47% in 2016 to 67% in 2017.The Last polio case reported in Liberia was in late 2010.

Conclusion: there was significant improvement in the key AFP surveillance indicators such as NPAFP rate and stool adequacy with a 3.5 fold increase in NPAFP from 2014 to 2017. By 2017, the stool adequacy rate was up to target levels compared to 2016, which was below target level of 80%. The number of counties meeting target for the two critical AFP surveillance indicators also increased by 20% points between 2016 and 2017. Similarly there was approximately two-fold increase in the oral polio vaccines (OPV) coverage for the reported AFP cases between 2015 and 2017. Strategies employed to address gaps in AFP surveillance included enhanced active case search for AFP, re-instatement of laboratory testing, supportive supervision in addition to facilitating enhanced community engagement in surveillance activities. New technologies such as AVADAR Pilot, electronic integrated supportive supervision (ISS) and electronic surveillance (eSurv) tools were introduced to improve real time AFP case reporting. However, there remain residual gaps in AFP surveillance in the country especially at the sub-national level. Similarly, the newly introduced technologies will require continued funding and capacity building for MOH staff to ensure sustainability of the initiatives.

Introduction

The global effort to eradicate polio is one of the largest public health initiatives under the global polio eradication initiative (GPEI) launched in 1988 [1]. Polio eradication is also seen as an early win for immunization program in the global vaccine action plan (GVAP) 2011-2020 [2]. The basic strategies for eradicating polio involve, routine immunization, supplemental immunization activities (SIAs), acute flaccid paralysis (AFP) surveillance and house-to-house mopping-up campaigns [1, 3]. The absence of WPV can only be determined by implementation and monitoring of robust AFP surveillance [1, 4]. Maintaining high quality and sensitive AFP surveillance system is important detect any re-emergence or re-introduction of the virus for timely response [1, 3-5]. Polio eradication initiative (PEI) in Liberia started in 2000 and achieved polio free certification 2008 [6]. The country experienced two waves of polio importation in 2009 with 11 WPV1 cases and in 2010 with two cases. However, the country has remained polio free since 2010 [6, 7] and maintained certification level AFP surveillance indicators each year until 2014 due to Ebola outbreak. Liberia has aligned with GPEI polio end game priorities to detect and interrupt all poliovirus transmission, strengthen immunization systems, introduce inactivated polio vaccine (IPV) and withdraw oral polio vaccines (OPV), contain poliovirus and certify interruption of transmission plan polio's legacy. This paper evaluates the AFP surveillance indicators and describes the results of AFP surveillance post-EVD outbreak in Liberia, demonstrating the rebound in AFP surveillance from 2015-2017 and identifying areas for improvement.

Methods

Study setting: Liberia is a tropical country in West Africa with a total land area of 111,370 km2. The country is bordered by Sierra Leone in the West, Cote d'Ivoire in the East, Guinea in the North and the Atlantic Ocean in the South. The insert in Figure 1 represents Montserrado County, hosting the nation's capital city Monrovia. It accounts for one third of the population of Liberia. It is densely populated with several urban slums and high level of population migration. The county dynamics is very diverse and complex. The country has an estimated population of about 4.1 million and an annual growth rate of 2.1%. There are 15 counties (equivalent to WHO districts) and 93 health districts (sub-districts). Based on the National Health Population Census (NHPC), there are more than 200 chiefdoms, 200 clans and 3,694 towns and human settlements within Liberia´s territorial confines national health population commission (NHPC, 2008). Liberia has distinct wet and dry season with the rainy season almost 9 months in the year. The communications and road network as well as the availability of energy sources and distribution is very limited. Accessibility within the country is a great challenge, especially during the rainy season. A total of 96 high priority, 162 medium priority and 546 low priority sites were identified during the period and active case visits conducted by surveillance personnel. The structure for surveillance consisted of the national focal person for Expanded Program on Immunization (EPI) surveillance. He/she worked closely with the county surveillance officers (CSOs) at the first sub-national level. The CSOs, supervise the district surveillance officers (DSOs). The DSOs in turn supervise the focal points at the health facility or community level. Regular meetings are held between staff at the various levels (national, county and community), to facilitate program coordination and implementation activities.

AFP surveillance process in Liberia: when a patient meeting the AFP case definition is seen at a health facility or in the community, the district surveillance officers are informed to conduct comprehensive investigations. These include taking a detailed history, conducting a systematic examination, and collecting two stool specimens, 24 to 48 hours apart, within 14 days of onset of symptoms. The stool samples are then transported via DHL to WHO-accredited Regional Reference Polio Laboratory (RRPL) in Abidjan, Cote d'Ivoire for virus isolation and identification. Laboratory results are relayed to the EPI and disease prevention and control (DPC) teams and the surveillance personnel at the sub-national level are required to provide feedback to both the health facilities and community members were the cases were identified. Emphasis was placed on AFP specimen that tested suspected poliovirus and requiring intratypic differentiation. Due to the lapse in AFP indicators during the Ebola outbreak, a series of interventions were implemented to strengthen the system for instance: the verification mechanisms of reported AFP cases at both national and sub-national levels were enhanced. At national and sub-national level, all AFP cases must be reviewed by surveillance personnel, WHO team to verify that the cases meet criteria as true AFP cases, stool specimen collected and sent to the national level. Regular coordination between the national surveillance officer, DPC teams and WHO teams for data sharing and weekly harmonization of surveillance data were conducted. Joint supportive supervision by immunization and surveillance personnel at national and sub-national levels was also conducted. Surveillance officers at county and district level were trained on AFP/ VPD surveillance and additional trainings during IDSR trainings. Clinicians, vaccination teams and general community health volunteers (gCHVs) were sensitized and required to conduct active case search in the communities and during activities such as polio SIAs and african vaccination week (AFW). Regular re-assessment of vulnerability of the surveillance system and prioritization of surveillance sites, identifying high risk areas at county levels and facilitate for prompt and appropriate actions. The use of electronic surveillance tools (ISS, eSurv and AVADAR supervision checklists) enhanced documentation of active surveillance activities. Reinforced AFP surveillance at international cross-borders and port of entry through the integrated diseases surveillance and response (IDSR) framework and during polio campaigns. Counties sharing common borders with Sierra Leone, Guinea and Cote d'Ivoire include Bong, Grand Cape Mount, Grand Gedeh, Nimba, Maryland and Lofa. The country has a national polio expert committee (NPEC) that meets quarterly to conduct final classification of all AFP cases. Liberia presented the annual polio certification updates for 2016 during the Africa Regional Certification Commission (ARCC) annual certification meeting in Malabu, Equatorial Guinea in 2017. The commission accepted the annual update and Liberia maintained her polio free status. An External VPD Surveillance Review in November 2016 supported by WHO and United States Centers for Disease Control and Prevention (CDC) to strengthen quality of VPD surveillance system. Following the review, surveillance improvement work-plan was jointly developed by the MoH and partners and implemented to strengthen the surveillance systems. Additionally, weekly VPD surveillance updates, auto visual AFP detection and reporting sitreps, monthly EPI Bulletin; monthly Brazzaville Initiative (B.I.) reports were produced and disseminated to inform actions.

New technologies: MOH partnered with WHO, Bill and Melinda Gates Foundation (BMGF), Novel-t and eHealth Africa to pilot auto visual AFP detection and reporting (AVADAR) to enhance community engagement with AFP detection and reporting in Montserrado County. Electronic Integrated Supportive Supervision (ISS) and electronic surveillance (eSurv) checklists were also introduced to enhance active cases search for AFP and other vaccine preventable diseases (VPDs) surveillance through supportive supervision. Within 8 months of introduction, MOH/ WHO staff conducted approximately 1,500 supportive supervision visits to health facilities and district teams in all 15 counties using the electronic supervision tools. Three level monitoring structure at National, County and District/ Community; with production and dissemination of information productions for action as shown in Figure 2.

Data analysis: Microsoft excel and access ware used data analysis. Data was collected using ODK mobile data application downloaded into smartphones. Data analysis was automatically done for electronic data in the AVADAR and ONA servers and was exported from the servers to excel spreadsheet for further analysis. Arc GIS was used to geo mapping of surveillance and polio campaign activities.

AFP Surveillance indicators: the WHO has devised a set of performance indicators to ensure that AFP surveillance is properly maintained. We evaluated the quality of the AFP surveillance using the WHO guidelines for minimum performance standards.

Ethical considerations: waiver for ethical approval for the study was obtained from the Liberia Ministry of Health and NPHIL with the confidentiality of patients was maintained during the study.

Results

During the review period, specimen collection and referral for testing for polio were conducted from all 15 counties. A total of 150 children under 15 years were screened for polio and confirmed negative for wild polio virus from Epi week 1,2016 to Epi week 52 2017. The AFP stool specimens were transported from the point of collection through riders for health or directly by surveillance officers to the national drug store in Monrovia. There the specimens are stored, packaged and transported by DHL Courier to the regional laboratory in Abidjan for testing. Reverse cold chain with appropriate stool storage in the dedicated carries were maintained at all levels. At the same time, 60 day follow-up was conducted for a total of 15 AFP cases and all were reclassified as non-polio cases by national polio expert committees. Re-enforced documentation of 60 day follow-up at both national and sub-national levels.

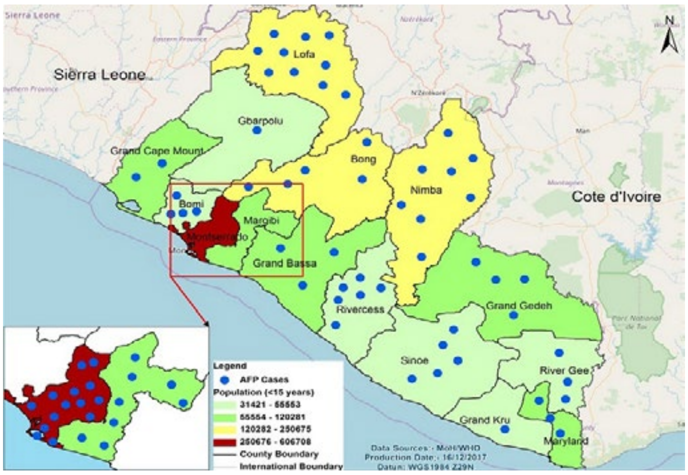

Figure 1: point map showing number of AFP cases reported by county as of Epi week 52 2017 Liberia

The map in Figure 1 shows the number and distribution by county of AFP cases reported in Liberia as of week 52, 2017. All counties reported at least one AFP case during the review period. Note that the map does not show exact location of the AFP cases as geo coordinates were not captured. However, new technologies such as AVADAR and electronic surveillance tools have the potential to address this gap. Overall there was significant improvement in AFP surveillance indicators during the review period with a rebound of non-polio AFP rate (NPAFP) from 1.2 in 2015 to 3.7 in 2016. As of Epi Week 52, 2017, the NPAFP rate was 4.2. The stool adequacy rate also improved from 79% in 2016 to 82% in 2017, meeting the global target. There was marginal improvement with AFP stool transport time from 47% in 2016 to 50% in 2017 for the reporting period. The % of counties meeting the 2 critical AFP surveillance indicators also improved from 47% in 2016 to 67% in 2017. For more results and other AFP indicators see Table 1 and Table 2, Table 2 (suite). The bar chart in Figure 3 shows that the number of AFP cases reported peaked during the first quarter and plateau for Q2-Q3, with decline between November and December. There was significant increase in the number of AFP cases reported in Q1, 2017 compared previous years. From the table, AFP cases were reported in 100% and 83% of months in 2016 and 2017 respectively.

Table 1: AFP surveillance indicators from 2013-2017 (Data Source: MOH/ WHO AFP Surveillance Database)

Indicators	Target	2013	2014	2015	2016	2017
Number of AFP cases Reported		50	23	22	69	81
Non-Polio AFP Rate	>=2/100,000 under 15 Pop.	2.9	1.9	1.2	3.7	4.2
Stool Adequacy Rate	>=80%	100%	96%	95%	79%	80%
Case investigation within 48 hours of report	>=90%	92%	100%	91%	89%	91%
Stool specimens arriving at the lab <3 days of being sent	>=80%	36%	55%	NA	47%	52%
Stool specimens arriving at the laboratory in "good condition"	>=90%	98%	100%	NA	100%	100%
Non Polio enterovirus rate (NPENT)	>=10%	8%	9%	0	12%	23%
% of counties meeting Non- Polio AFP rate and stool adequacy rate	>=80%	80%	60%	53%	47%	67%
60 days follow up	All cases (L)					

Table 2: AFP surveillance statistics by county and indicators for 2015 -2016, Liberia (Data Source: MOH/ WHO AFP Surveillance Database)

Year	County	Total AFP cases	Age			Sex		Total polio dases			Durtation from onset-notifi.		Duration from notifi-invest.		Duration from 1st stool -2nd stool		Duration from Onset -2nd stool		2nd stool-national lab		Indicators		
								dose			days		days		days		days		days				
			0-4	5 to 9	>=10	1	2	<3	>=3	unknown	<=7	>7	<=2	>2	<=2	>2	<=14	>14	<=3	>3	NPAFP	Stool A	NPENT
2015	Bomi	1	1	0	0	1	0	0	1	0	1	0	0	1	1	0	1	0	0	1	2.3	100%	0%
	Bong	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NA	0%
	Gbarpolu	1	1	0	0	1	0	1	0	0	1	0	0	1	1	0	1	0	0	1	2.3	100%	0%
	Grand Bassa	3	3	0	0	0	3	1	1	1	2	1	3	0	3	0	2	1	0	3	2.6	100%	0%
	Grand Cape Mount	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NA	0%
	Grand gedeh	2	2	0	0	0	2	0	1	1	2	0	2	0	2	0	2	0	0	2	3.1	100%	0%
	Grand kru	1	0	1	0	1	0	0	0	1	1	0	1	0	1	0	1	0	0	1	3.3	100%	0%
	Lofa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NA	0%
	Margibi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NA	0%
	Maryland	2	1	0	1	1	1	0	0	2	2	0	2	0	2	0	2	0	0	2	2.8	100%	0%
	Montserrado	5	2	3	0	2	3	2	3	0	5	0	5	0	5	0	5	0	0	5	0.9	100%	0%
	Nimba	5	3	2	0	1	4	3	2	0	5	0	5	0	5	0	5	0	0	5	2.1	100%	0%
	Rivercess	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	NA	0%
	River Gee	1	1	0	0	1	0	0	0	0	1	0	1	0	1	0	1	0	0	1	2.7	100%	0%
	Sinoe	1	0	0	1	1	0	0	0	1	0	1	1	0	1	0	1	0	0	1	1.9	100%	0%

Sex: 1 = female; 2 = male

Table 2 (suite): AFP surveillance statistics by county and indicators for 2015 -2016, Liberia (Data Source: MOH/ WHO AFP Surveillance Database)

Year	County	Total AFP cases	Age			Sex		Total polio dases			Durtation from onset-notifi.		Duration from notifi-invest.		Duration from 1st stool -2nd stool		Duration from Onset -2nd stool		2nd stool-national lab		Indicators		
								dose			days		days		days		days		days				
			0-4	5 to 9	>=10	1	2	<3	>=3	unknown	<=7	>7	<=2	>2	<=2	>2	<=14	>14	<=3	>3	NPAFP	Stool A	NPENT
2016	Bomi	4	4	0	0	1	3	1	3	0	3	1	3	1	4	0	4	0	3	1	8.9	100%	50%
	Bong	11	7	3	1	5	6	2	5	4	4	7	11	0	11	0	6	5	5	6	6.2	55%	18%
	Gbarpolu	1	1	0	0	0	1	1	0	0	1	0	1	0	1	0	1	0	0	1	2.3	100%	0%
	Grand Bassa	3	3	0	0	2	1	1	0	2	1	2	3	0	3	0	2	1	0	3	2.5	67%	67%
	Grand Cape Mount	3	3	0	0	2	1	0	3	0	3	0	1	2	3	0	3	0	2	1	4.4	100%	33%
	Grand gedeh	3	1	1	1	2	1	3	0	0	2	1	2	1	3	0	2	1	1	2	4.5	100%	0%
	Grand kru	2	2	0	0	0	2	1	1	0	2	0	2	0	2	0	2	0	0	2	6.5	100%	0%
	Lofa	7	4	2	1	2	5	2	3	2	7	0	6	1	7	0	7	0	1	6	4.8	100%	0%
	Margibi	5	5	0	0	3	2	3	2	0	5	0	4	1	5	0	5	0	2	3	4.5	100%	40%
	Maryland	3	2	1	0	3	0	2	1	0	1	2	3	0	3	0	1	2	0	3	2.8	100%	0%
	Montserrado	13	8	4	1	6	7	2	6	5	7	6	12	1	13	0	8	5	9	4	2.2	62%	54%
	Nimba	7	3	1	3	3	4	0	6	1	4	3	7	0	7	0	5	2	6	1	2.9	71%	14%
	Rivercess	1	1	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0	0	1	2.8	100%	0%
	River Gee	2	1	1	0	0	2	0	2	0	1	1	2	0	2	0	1	1	1	1	5.3	50%	0%
	Sinoe	4	3	1	0	3	1	1	1	2	3	1	4	0	4	0	4	0	0	4	7.4	100%	50%

Sex: 1 = female; 2 = male

The majority of the reported AFP cases from 2015-2017 were below 5 years of age (n = 112, 65%) and 55% were female. 66% of the AFP cases were notified in less than 7 days from date of symptom onset, with Montserrado, Nimba and Bong Counties accounting for most of the cases notified in more than 7 days from symptom onset. Furthermore, 90% of the AFP cases reported were investigated within 24 hours of notification while the 99% of the 2 stool specimens were collected 24 hours apart. The numbers in Table 2, Table 2 (suite) and Table 3 shows that there was significant improvement in the reported number of OPV doses received by the AFP cases for the period under review. There was approximately a two-fold increase in the number of OPV doses received by AFP cases from 36% in 2015 to 61% in 2017. However, 20% (32/168) of the cases reported unknown number of OPV doses received. In 2015, 0% of AFP stool specimen tested negative for NPENT, while % of NPENT increased from 12% in 2016 to 23% in 2017. Gbarpolu, Maryland, Grand Kru counties did not have any stool specimen positive NPENT between 2015-2017. 52% of stool reached the national level within 72 hours of 2nd stool collection in 2017, an increase from 44% in 2016. Improvement in stool transport times were most evident in Gbarpolu, Grand Bassa, Lofa, Maryland, Rivercess and Sineo Counties, while there was an increase in stool transport times for Nimba, Bomi, Montserrado counties. In Figure 4, it was shown that AVADAR Pilot improved AFP reporting in pilot sites with 12 AFP cases reported between Epi week 11- Epi week 50 2017 compared to 3 AFP cases reported in same pilot sites at same reporting period in 2016. AVADAR Pilot contributed to improve AFP case detection and reporting in previously silent districts as Careysburg district during the period under review. A total of 822 supportive supervision visits were conducted using the eSurv checklist. The checklists were used in all 15 counties. However, there are still areas in some counties were the eSurv checklist have not been used. This can be explained as the eSurv checklist was initially used to 8 counties where Stop the Transmission of Polio (STOP) team were deployed before scaling-up to all 15 counties in Q3, 2017. The aim was to first learn by doing, and subsequently scale up nationwide.

Table 3: AFP Surveillance statistics by county and indicators for 2017, Liberia (Data Source: MOH/ WHO AFP Surveillance Database)

Year	County	Total AFP cases	Age			Sex		Total polio dases			Durtation from onset-notifi.		Duration from notifi-invest.		Duration from 1st stool -2nd stool		Duration from Onset -2nd stool		2nd stool-national lab				Indicators
								Doses			Days		Days		Days		Days		Days				
			0-4	5 to 9	>=10	1	2	<3	>=3	unknown	<=7	>7	<=2	>2	<=2	>2	<=14	>14	<=3	>3	NPAFP	Stool A	NPENT
2017	Bomi	4	3	1	0	1	3	0	4	0	`	2	4	0	4	0	4	0	2	2	8.8	100%	25%
	Bong	5	3	1	1	4	1	0	3	2	5	0	5	0	4	1	5	0	2	3	2.9	100%	0%
	Gbarpolu	2	2	0	0	1	1	1	1	0	1	1	2	0	2	0	1	1	1	1	4.7	50%	0%
	Grand Bassa	4	2	1	1	2	2	1	2	1	2	2	4	0	4	0	3	1	3	1	3.5	50%	50%
	Grand Cape Mount	2	2	0	0		2	0	2	0	1	1	2	0	2	0	2	0	2	1	3.1	100%	0%
	Grand gedeh	4	3	1	0	1	3	1	3	0	4	0	4	0	4	0	4	0	1	3	6.2	100%	50%
	Grand kru	1	1	0	0	1		0	0	1	0	1	1	0	1	0	0	1	0	1	3.4	0%	0%
	Lofa	10	3	5	2	5	5	2	8	0	6	4	6	4	10	0	9	1	5	4	7.1	90%	10%
	Margibi	8	5	2	1	2	6	5	3	0	8	0	8	0	8	0	8	0	5	3	7.5	100%	25%
	Maryland	3	2	1	0	3		2	0	1	0	3	3	0	3	0	2	1	1	2	4.3	67%	0%
	Montserrado	16	12	2	2	7	9	4	11	1	7	9	16	0	16	0	10	6	8	8	2.8	63%	13%
	Nimba	8	5	1	2	4	4	3	5	0	4	4	7	1	8	0	8	0	6	2	3.4	100%	13%
	Rivercess	6	5	1	0	1	5	1	4	1	3	3	5	1	6	0	5	1	3	3	17.6	83%	50%
	River Gee	3	3	0	0		3	0	2	1	1	2	2	1	3	0	1	2	1	2	8.2	33%	67%
	Sinoe	5	4	0	1	2	3	1	1	3	4	1	5	0	5	0	4	1	2	3	9.6	80%	0%

1 = female; 2 = male

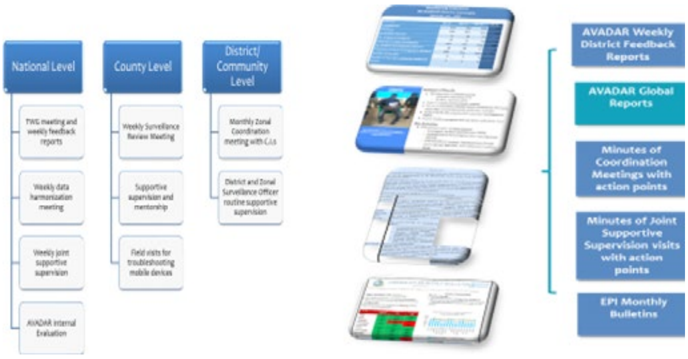

Figure 2: three level monitoring structure at National, County and District levels

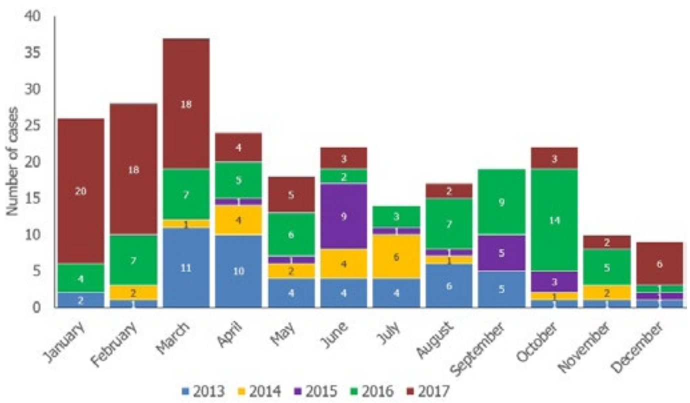

Figure 3: showing the number of AFP cases reported by month from 2013-2017, Liberia

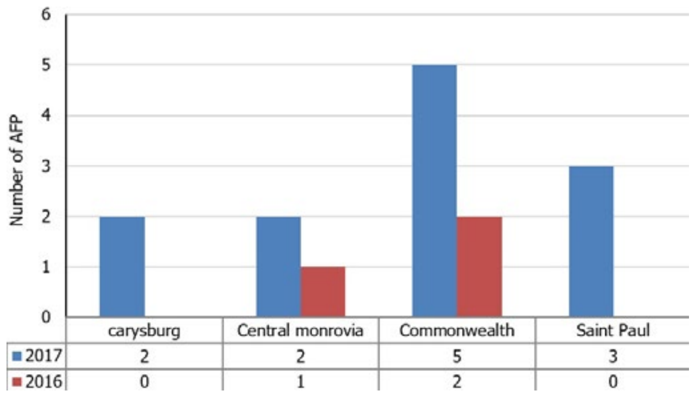

Figure 4: number of cases reported in AVADAR districts 2017 and 2016

Discussion

As per the desk review, there was significant improvement in the key AFP surveillance indicators between 2014 and 2017 in Liberia such as Non Polio AFP Rate (NPAFP) rate and stool adequacy with a 3.5 fold increase in NPAFP from 2014 to 2017 and with stool adequacy rate reaching global target levels by 2017. The number of counties meeting target for the two critical AFP surveillance indicators also increased by 20% points between 2016 and 2017. Similarly there was approximately two-fold increase in the number of OPV doses received by the reported AFP cases between 2015 and 2017. These improvements with the AFP surveillance indicators can be related to the key activities done in order to improve the capacity and structures of the surveillance system following the EVD outbreak control. For instance, integration of the AFP surveillance within the IDSR framework, improved supportive supervision by surveillance officers and partners, capacity building for surveillance personnel and clinicians, including sensitization and engagement of community health volunteers as well as the high emphasis given for AFP surveillance during Polio NID's. It also demonstrates the improvement with immunization coverage as more AFP cases were reportedly vaccinated with OPV during the period. From the study, majority of the AFP cases were aged less than 5 years at 65% of total reported cases. This is similar to other studies [8] where 82.5%, 74.3% of the AFP cases below 5 years and demonstrates the most at risk population for AFP and polio cases. Of the total cases reported, 55% were female. AFP case reporting appears to show season variations with more cases reported in Q1 and between September and October. This is similar to other studies [6, 9] showing increased AFP cases reported March and September. This may be associated with the increased capacity to conduct active search for AFP during polio SIAs usually during these months with increased number of health workers and community volunteers deployed for the immunization campaigns. Although during the period under review, AFP cases were reported an average of 90% of the months, heightened AFP case search is required with the same intensity throughout the year to ensure no cases are missed.

Although there were significant rebound of surveillance indicators following restoration of health system recovery, there are still residual gaps in the AFP surveillance with respect to stool transport times and percentage of counties meeting both key AFP surveillance indicators (stool adequacy and NPAFP rate) and percentage of AFP cases receiving three or more doses of Oral Polio Vaccine (OPV) doses at the end of 2017. The residual gap with stool adequacy is associated with the fact only a 66% of the AFP cases were notified in less than seven days from date of symptom onset, thus increasing the chances that collection of stool specimen maybe delayed. This delay in notification of AFP cases within seven days is most pronounced in Montserrado, Nimba and Bong Counties and these counties had inadequate stool specimen during the period under review. However, the study also show that when the AFP cases are notified, response time by the surveillance officers were rapid, for instance 90% of the AFP cases reported were investigated within 24 hours of notification while the 99% of the 2 stool specimen were collected 24 hours apart. This shows that more emphasis should be on active case search for AFP cases and sustained rapid response of the surveillance officers. Some of the contributing factors to residual AFP surveillance gaps include quantity and capacity of surveillance personnel, inadequate surveillance logistics especially for hard to reach areas and sub-optimal community participation for surveillance activities as also highlighted in literature elsewhere [1, 8]. The duration of AFP stool transport time is a critical factor for AFP surveillance as it influences the rate of identification and response for any positive polio case and the quality of stool specimen being tested. Although this paper shows improvement with AFP transport times from 44% in 2016 to 52% in 2017, it still remains below WHO recommended target levels of 80% [5]. From the study, the hard-to-reach counties contributed to the delayed transport times due to poor road access, however some easily accessible counties like Montserrado, Bomi and Bong counties also had delayed AFP transport times. This is very pronounced in the case of Montserrado County which hosts the national depot. Thus there is a need to further review and understand the reasons for long transport times in the county as well as in addressing this gap.

One of the other important AFP surveillance indicators is the Non Polio Entrovirus Rate (NPENT) rate which shows the integrity of stool specimen tested for viral isolation and quality of the reverse cold chain. According to the WHO AFRO region AFP surveillance guideline, the laboratory should be able to isolate the Non-Polio Entero virus in at least from 10% of the total stool samples collected and sent. So, review showed that, there was steady improvement of NPENT rate at the national level from 0% in 2015 to 12% in 2016 and 23% in 2017 [5]. The hard-to-reach counties such as Gbarpolu, Maryland, Grand Kru counties did not have any stool specimen positive NPENT between 2015-2017. As highlighted earlier, the delay in transport time may contribute to the quality of reverse cold chain as it becomes more difficult to maintain as time elapses. Maintaining high level of AFP surveillance is a cornerstone of polio eradication especially for areas with low OPV coverage and risk of polio importation and will require continuous evaluation and assessment of the surveillance system to identify areas of gaps and addressing them [1, 8]. Here the role of operational research for polio eradication remains imperative for AFP surveillance [1, 10]. Liberia immunization program working in the context of IDSR actively uses data to inform strategies to improve and maintain robust AFP surveillance system, for instance in addition to routine M&E systems, the program along with WHO and partners conducted an external VPD surveillance in 2016 to assess the quality surveillance, preparedness and response system [11] in addition to other evaluations. From the study, AFP surveillance system was geographically spread in all 15 counties, including the counties that had lower OPV coverage. However, more efforts should be made to identify all high-risk communities and underserved populations to ensure population immunity and that no polio cases are missed in these areas.

Additionally, key strategies employed to address some of these gaps in AFP surveillance include introduction of new technologies such as AVADAR Pilot, eSurv and ISS electronic surveillance tools which improved the surveillance system. These innovation leverage on technology to strengthen real time AFP case reporting, supportive supervision and accountability mechanism for surveillance personnel. They also facilitate enhanced community engagement in surveillance activities. High level participation and government ownership to introduce the technologies [12] contributed to the success of implementation and contributed to strengthen the surveillance system, demonstrating the capacity of Liberia to adopt and adapt to new technologies. This is especially important as various new technologies such as mobile data collection, GIS, big data and artificial intelligence with capacity to improve health service delivery are being rolled-out simultaneously in developed and developing countries [13-16] and thus Liberia is in a strong position to leverage on technology to improve her immunization program and overall health system. Additionally, these technologies have the capacity to strengthen record keeping and documentation of AFP surveillance activities, as the quality of AFP surveillance is as good as the documented evidence of the activities conducted, as it is the only way to demonstrate the quality of the surveillance system [17]. Furthermore, documentation of AFP surveillance activities and other Polio eradication program (PEP) activities is critical to maintaining polio free certification and archiving of legacy of polio eradication in Liberia [1, 14, 18-20]. On this note, there are various ways in which AFP surveillance can contribute to the polio legacy and continued strengthening of the overall health system [18, 19]. For instance, the PEP personnel at both national and sub-national level contributing to build capacity of district teams and health workers on immunization service delivery and VPD surveillance. The logistic supplies for AFP surveillance also support surveillance for other VPDs and integrated supportive supervision for immunization activities [21-23]. Furthermore, the introduction of new technologies is already being leveraged by other programs especially the IDSR team to strengthen real time data collection, supportive supervision, feedback systems and accountability systems for staff in Liberia.

Conclusion

During the period under review, Liberia demonstrated strong rebound in AFP surveillance indicators as the country restored essential health service delivery following significant decline due to the devastating EVD outbreak in 2014-2015. These improvements were most significant in the two critical AFP surveillance indicators at the national level, thus ensuring high level vigilance for AFP cases in line with polio end game activities. These improvements were due to significant human and material resources deployed to rejuvenate the surveillance systems post EVD within investment plan for rebuilding a resilient health system. However, more needs to be done to sustain the gains made thus and further improve the system especially at the sub-national level. Here, some counties perform sub-optimally in some AFP surveillance indicators predisposing to risk of missing any polio case. On this note, Liberia is working closely with partners to pilot and deploy innovations to strengthen surveillance systems especially in areas that are at high risk to polio importations.

What is known about this topic

- Devastating impact of Ebola outbreak on health systems and performance indicators in affected countries;
- Use of AFP surveillance system for early case identification of VPDs and Ebola virus in different countries;
- Use of technology to strengthen AFP surveillance and other polio eradication activities in other countries.

What this study adds

- Experience of Liberia in reviving AFP surveillance indicators following Ebola outbreak;
- Strategies deployed to improve AFP surveillance indicators in Liberia;
- Presence of residual gaps which needs improvement to maintain Polio certification in Liberia.

Competing interests

The authors declare no competing interest.

Authors' contributions

Authors conceived idea, with support from WHO scrutinized and identified the most appropriate literature. Authors analyzed, synthesized and wrote the first draft of the manuscript. WHO provided further insights. Authors read and approved the final version of the manuscript.

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Research

The implementation of integrated disease surveillance and response in Liberia after Ebola virus disease outbreak 2015-2017

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Abstract

Introduction: although Liberia adapted the integrated diseases surveillance and response (IDSR) in 2004 as a platform for implementation of International Health Regulation (IHR (2005)), IDSR was not actively implemented until 2015. Some innovations and best practices were observed during the implementation of IDSR in Liberia after Ebola virus disease outbreak. This paper describes the different approaches used for implementation of IDSR in Liberia from 2015 to 2017.

Methods: we conducted a cross-sectional study using the findings from IDSR supervisions conducted from September to November 2017 and perused the outbreaks linelists submitted by the counties to the national level from January to December 2017 and key documents available at the national level.

Results: in 2017, the country piloted the use of mobile phones application to store and send data from the health facilities to the national level. In addition, an electronic platform for acute flaccid paralysis (AFP) surveillance called Auto-Visual AFP Detection and Reporting (AVADAR) was piloted in Montserrado County during the first semester of 2017. The timeliness and completeness of reports submitted from the counties to national level were above the target of 80% stable despite the challenges like insufficient resources, including skilled staff.

Conclusion: IDSR is being actively implemented in Liberia since 2015. Although the country is facing the same challenges as other countries during the early stages of implementation of IDSR, the several innovations were implemented in a short time. The surveillance system reveled to be resilient, despite the challenges.

Introduction

Public health surveillance systems are crucial for detection of unusual trends of diseases or public health events. However, it requires skilled staff, good information system and good laboratory capacity for cases confirmation [1]. Weak surveillance systems, unable to detect early public health emergencies including early stage of outbreaks are public health challenges in several african countries. This weakness contributed to a late recognition of Ebola virus disease (EVD) outbreak in West Africa in 2014, where Liberia, Sierra Leone and Guinea were the most affected countries [2-5]. The World Health Organization (WHO) framework for monitoring and evaluating surveillance and response systems for communicable disease with core and support functions, from which surveillance indicators were derived was adapted by several countries including Liberia [6]. Liberia adapted the integrated diseases surveillance and response (IDSR) in 2004 as a platform for implementation of International Health Regulation (IHR (2005)). Although some progress has been observed over the years, the poor health care facility (HCF) reporting and the inadequate response remained challenges that became obvious after the EVD outbreak [7]. Nevertheless, the outbreak was a good opportunity to strength the surveillance systems in Liberia, and staff were trained, new laboratories were opened and EVD surveillance was also strengthened at the community level [8, 9]. After the control of EVD, the implementation of IDSR was focused not only on case detection but also on response to other priority diseases and public health events [7]. The strengthening of IDSR is part of the investment plan to build a resilient health system in Liberia [10]. Some innovations and best practices were observed during the implementation of IDSR in Liberia after EVD outbreak, as well as dramatic improvement on case detection and response to several outbreaks and public health events. This paper describes the different approaches used for implementation of IDSR in Liberia after EVD outbreak, innovations, best practices and lessons learned.

Methods

Setting

Liberia is one of west african countries with a population of 3,489,072 and a population density of 93 people per square mile according to the census 2008 [11]. The country is divided into 15 counties and five main regions, namely [12]: 1) North Western: Bomi, Gbarpolu and Grand Cape Mount counties; 2) South Central: Grand Bassa, Margibi and Montserrado counties; 3) North Central: Bong, Lofa and Nimba counties; 4) South Eastern A: Grand Gedeh, River Cess and Sinoe counties; 5) South Eastern B: Grand Kru, Maryland and River Gee. Montserrado County alone has 33% of population of the entire country and is classified as a very densely populated county, while the south eastern and Gbarpolu counties have small and sparse population [11]. The 15 counties are divided into 90 districts in the country. Due to the huge population, Montserrado County is further divided into 22 health zones.

Study design

We conducted a cross-sectional study in December 2017 using the IDSR supervisions secondary data collected from September to November, 2017. A supervision checklist was used by the district surveillance officers (DSOs) and zonal surveillance officers (ZSOs) to supervise monthly all the 773 HCFs across the country as part of their routine activities. The supervision checklist was completed using the information provided by the head of the health facility. Besides the review of patient charts, ledgers and lab records, the DSOs and ZSOs also observed directly the presence of guidelines, case definitions and recording and submission of reports. However, from September to November, 2017, 384 HCFs (50%) were supervised at least once and the data used in our analysis (Table 1). The supervision checklist included 65 variables and the qualitative question "What are the major areas for improvement in surveillance activities in this HCF?". The outbreaks line lists submitted by the counties to the national level from January to December 2017 were used to analyze the outbreaks investigated and the respective IDSR performance indicators. We organized and analyzed the findings according to IDSR core functions, namely case detection, case registration, case notification, data management, data analysis, outbreak preparedness, outbreak detection, outbreak response and feedback, as well as support functions, namely supervision, training, laboratory function, resources and coordination suggested by WHO [6, 13]. We also perused key documents available at the national level, namely, two IDSR technical guidelines for Liberia, IDSR bulletins published at the National Public Health Institute of Liberia (NPHIL) website, outbreaks investigations reports and the Lab records available at NPHIL database from January to December 2017.

Data analysis

Qualitative data: all the qualitative data from supervision checklist (opinion of the health workers about the major areas for improvement in their HCF) were stored in Microsoft™ Excel. We organized all the answers manually to fit into each of the IDSR functions. The qualitative data obtain through direct observation and relevant reports were recorded as a text and organized according to the IDSR functions.

Quantitative data: the quantitative data from supervision checklist were also stored and analyzed in Microsoft™ Excel. From the 65 indicators, we included in analysis only the data fitting in the IDSR functions and with information available from all the 384 HCFs assessed.

Ethical considerations: the IDSR activities were part of the routine surveillance and response activities in Liberia. Therefore, no ethical approval was required. The secondary data analysis and publication was authorized by the National Public Health Institution of Liberia. No personal information and confidential data was disclosed.

Results

Structure of integrated diseases surveillance and response in Liberia: poliomyelitis, meningitis, cholera, shigellosis, Lassa fever, measles, rabies, viral hemorrhagic fever, neonatal tetanus, yellow fever, maternal deaths, neonatal deaths and unexplained cluster of deaths or health events were the priority diseases and events to be reported weekly in Liberia under IDSR. In Liberia, the IDSR data were collected first from the communities and points of entry and submitted subsequently to the HCFs, district, county and national levels. In 2017, 88% (679/773) of the facilities were classified as clinic, 7% (55/773) health centers, 5% (38/773) hospitals and < 1% (3/773) health posts. The majority of the HCFs [40% (290/773)] were concentrated in Montserrado County, 83% (240/290) of them classified as private. The surveillance system in Liberia received regular reports from 96% (285/296) of the private HCFs across the country. At the community level, the community health assistants and community health volunteers were responsible for surveillance system and were supervised by community health services supervisors (CHSSs) from the HCFs.

Core functions

Case detection: the case definitions of the priority diseases were simplified into a non-technical language and distributed to the community volunteers. During the 2017 assessment, the community case definitions were also pined on the walls in 92% (353/384) of HCFs (Table 1). In addition, 95% (349/384) of the HCFs had pinned on wall standard case definitions and the alert and epidemic threshold charts were present in 70% (369/384) of HCFs. The number of cases of priority diseases detected in the community represented 26% (100/384) of all the cases (Figure 1). Some officers in charge (OICs) disclosed that they do not use the case definitions due to limitations in understanding them and understand the thresholds. Other OICs highlighted the early detection of priority disease will improve with more awareness about the priority diseases at the community level and with active case search at community and facility level.

Case registration: the cases were recorded first in the patient's charts with clinical data and later transferred to the patients ledgers which included all the diagnosis in the HCFs. There were both adults and under-five years old patients ledgers. A recorder was responsible for filling the IDSR ledgers daily and make sure no priority disease were missed. During the 2017 assessment, all the indicators performed above the target of 80% except the case review forms for maternal and neonatal death that were present in 71% (269/384) of the HCFs (Table 1). The need of more reporting tools was also pointed by an OIC, as a challenge, while the other OIC disclosed that usually forgets to send the zero reports.

Table 1: performance of integrated diseases surveillance and response selected indicators, Liberia September to November, 2017							
Integrated disease surveillance and response function	Liberia Target (%)	%Southeastern A (n=29)	%Southeastern B (n=16)	%North Central (n=113)	%South Central (n=162)	%South Western (n=64)	%Liberia (n=384)
Case detection							
Community simplified case definitions pinned on wall	80	88	92	97	89	92	92
IDSR Standard case definitions pinned on wall	80	93	97	98	93	92	95
Alert and epidemic threshold charts updated within the past 1 month	80	70	70	67	62	83	70
Case registration							
Laboratory registers	80	98	87	79	68	80	82
HMIS monthly reporting forms with a correctly filled IPD/OPD section	80	100	100	96	98	98	99
Facility patient registers	80	100	100	100	100	96	99
IDSR case alert and lab submission forms	80	98	95	99	95	95	96
Community trigger and referral forms	80	70	100	77	81	88	83
Case review forms for maternal and neonatal death	80	65	86	72	74	57	71
Outbreak preparedness							
IPC protocols available	80	93	64	85	76	91	82
Outbreak detection							
Line list of alerts and rumors from the community	80	60	50	36	36	50	46
Trainings							
Surveillance Focal Person trained in the IDSR in the past 1 year	80	27	78	29	42	56	46
HCFs with staff trained to collect oral swab	80	95	67	89	36	93	76
CHVs/CHAs trained in CEBS in the catchment area in the past 1 year	80	100	97	84	47	90	84
Supervisions							
% HCFs supervised[a]	80	37	26	60	44	89	50
HCFs that received Supervision feedback report from district/county in the last four weeks	80	95	97	92	87	95	93
HCFs conducting supervisory visits to the CHVs and CHAs	80	97	86	77	60	90	82
Resources							
Means of communication to communities to the district	80	89	100	99	86	97	94
Adequate and functioning transport, including fuel, for surveillance activities	80	53	82	53	20	80	58
Standards and guidelines							
IDSR Technical Guidelines available	80	67	50	57	60	96	66
SOPs for dead body management available	80	66	86	74	57	87	74
The lab SOPs for specimen collection, packaging, and storage for priority diseases available	80	57	92	67	79	85	76

Table 2: outbreaks investigated with cases confirmed by laboratory, Liberia, January to December, 2017																		
	South Eastern A			South Eastern B			North Western			South Central			North Central			Liberia		
	Cases	Deaths	CFR (%)	Cases	Deaths	CFR (%)	Cases	Deaths	CFR (%)	Cases	Deaths	CFR (%)	Cases	Deaths	CFR (%)	Cases	Deaths	CFR (%)
Shigellosis[a]																		
Total Cases	74	0	0.0	11	0	0.0	14	0	0	107	0	0.0	18	0	0.0	224	0	0.0
Lab Confirmed	5	0	0.0	0	0	NA	1	0	0	6	0	0.0	2	0	0.0	14	0	0.0
Human Rabies[b]																		
Total Cases	146	2	1.4	80	1	1.3	70	0	0	709	0	0.0	284	0	0.0	1289	3	0.2
Lab Confirmed	0	0	NA	0	0	NA	0	0	NA	1	1	NA	0	0	NA	1	1	100.0
Cholera[a]																		
Total Cases	28	0	0.0	16	0	0.0	6	0	0	28	3	10.7	12	2	16.7	90	5	5.6
Lab Confirmed	1	0	0.0	1	0	0.0	0	0	NA	0	0	NA	0	0	NA	2	0	0.0
Lassa fever																		
Total Cases	2	0	0.0	0	0	NA	0	0	NA	18	6	33.3	41	13	31.7	61	19	31.1
Lab Confirmed	0	0	NA	1	0	0.0	0	0	NA	11	1	9.1	17	10	58.8	29	11	37.9
Measles																		
Total Cases	35	0	0.0	18	0	0.0	77	0	0	317	1	0.3	305	0	0.0	752	1	0.1
Lab Confirmed	5	0	0.0	3	0	0.0	5	0	0	96	0	0.0	110	0	0.0	219	0	0.0
Meningococcal Disease																		
Total Cases	1	1	100.0	15	1	6.7	3	0	0	7	3	42.9	6	0	0.0	32	5	15.6
Lab Confirmed	13	9	69.2	0	0	NA	0	0	NA	2	1	50.0	0	0	NA	15	10	66.7
Rubella[c]																		
Total Cases	33	0	0.0	11	0	0.0	47	0	0	120	0	0.0	104	0	0.0	315	0	0.0
Lab Confirmed	33	0	0.0	11	0	0.0	47	0	0	120	0	0.0	104	0	0.0	315	0	0.0
a)The outbreak was not declared because the epidemic threshold according to the national IDSR guidelines was not reached; b) Besides one lab confirmed case in France, the cases that ended in death were confirmed clinically; c)The outbreak was identified through labs tests of the suspected measles cases. Sinoe and Bomi counties did report any measles conformed cases but detected rubella confirmed cases.																		

Case confirmation: the peripheral clinics were equipped to perform rapid diagnostic test for malaria, typhoid fever, human immunodeficiency virus, syphilis and hepatitis B and urinalysis. Some clinics could also do microscopy for tuberculosis, malaria and stool tests. The referral hospital could perform gram test for meningitis, microscopy for malaria and stool test. The regional Labs could test for viral hemorrhagic fever like EVD, yellow fever and lassa fever. From January to December 2017, the country was able to confirm outbreaks of seven different conditions (Table 2).

Case notification: the priority diseases were reported on weekly basis to the immediately next level by the surveillance focal person, while the non-priority diseases were reported monthly to the county data managers. However, the immediately reportable diseases according to IHR were reported in a shortest time possible after identification. During 2017, 87% (4364/5016) of the priority diseases cases notified were linelisted and 86% (4314/5016) were notified from the facility to district level within 24 hours (Figure 1).

Data management: the data collected in the communities and from the entry points were submitted in hard copies to the HCFs and the immediate reportable diseases data were stored in both hard copies and DSOs computers to be submitted every week to the county level. The other conditions were sent to the county level in hard copies every month. At the county level, all the reports were compiled, stored in the computers and submitted to the national level. While the immediate reportable diseases were submitted in excel sheets, the other diseases were submitted through health management information system (HMIS). In 2017, the country piloted the use of mobile phones application [Open Data Kit (ODK) ©] to store and send data from the HCFs to the national level by the DSOs. Each level was retains one copy of the reports submitted to the next level for future inspections. An electronic platform for acute flaccid paralysis (AFP) surveillance called Auto-Visual AFP Detection and Reporting (AVADAR) was piloted in Montserrado County in 2017 and electronic IDSR piloted in Margibi and Grand Cape Mount Counties. One of the OICs highlighted the need of harmonization of HMIS and IDSR from the HCF perspective as a way to improve IDSR data management at HCF level.

Data analysis: at the county level, the data was presented in graphs and tables by the county surveillance officer (CSO) and WHO epidemiologists. All the 15 county surveillance officers analyzed data at least once a month and presented the findings to the county health team's supervisors and

Table 3: outbreaks investigated with no cases confirmed by laboratory, Liberia, January to December, 2017

	South Eastern A			South Eastern B			North Western			South Central			North Central			Liberia		
	Cases	Deaths	CFR (%)	Cases	Deaths	CFR (%)	Cases	Deaths	CFR (%)	Cases	Deaths	CFR (%)	Cases	Deaths	CFR (%)	Cases	Deaths	CFR (%)
Acute Flaccid Paralysis [a]	97	1	1.0	5	0	0.0	11	0	0.0	34	0	0.0	104	0	0.0	251	1	0.4
Chicken pox[b]	2	0	0.0	1	0	0.0	0	0	NA	14	0	0.0	0	0	NA	17	0	0.0
Monkey pox[c]	1	0	0.0	1	0	0.0	2	0	0.0	0	0	NA	0	0	NA	4	0	0.0
Neonatal Tetanus[b]	1	1	100.0	3	0	0.0	3	0	0.0	13	4	30.8	2	0	0.0	22	5	22.7
Pertussis[b]	110	0	0.0	10	0	0.0	0	0	NA	72	0	0.0	0	0	NA	192	0	0.0
Scabies[b]	7	0	0.0	42	0	0.0	3	0	0.0	0	0	NA	0	0	NA	52	0	0.0
Skin rashes [b, d]	38	0	0.0	0	0	NA	0	0	NA	0	0	NA	0	0	NA	38	0	0.0
Unexplained cluster of Health event[d]	3	0	0.0	10	0	0.0	0	0	NA	16	3	18.8	0	0	NA	29	3	10.3
VHF(including EVD)[e]	53	32	60.4	56	47	83.9	17	15	88.2	70	64	91.4	99	81	81.8	295	239	81.0
Yellow fever[f]	3	0	0.0	39	0	0.0	45	0	0.0	11	0	0.0	5	1	20.0	103	1	1.0
Unexplained Cluster of Death[d]		6			3			0			2			0			11	
Maternal death		25			22			14			90			74			225	
Neonatal death		41			133			20			242			144			580	

a)The Acute flaccid paralysis cases were tested for poliomyelitis and all the results came negative; b) Outbreak was confirmed clinically with no lab test performed; c) Outbreak was not confirmed with no lab test performed; d) There was no conclusion about the nature of the event e) The outbreak was not confirmed after all the lab results test negative for viral hemorrhagic fever (VHF) including Ebola virus disease; f)The rapid test performed in Liberia was positive for yellow fever but the confirmatory test performed in Senegal came negative and the outbreak was not confirmed

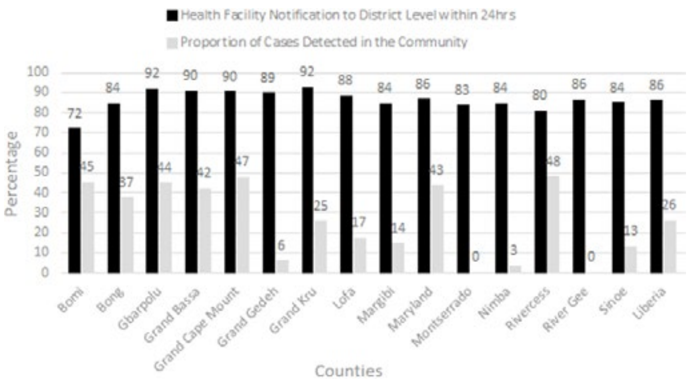

Figure 1: integrated diseases surveillance and response performance indicators for outbreak detection and notification from the health facilities and communities, Liberia, 2017

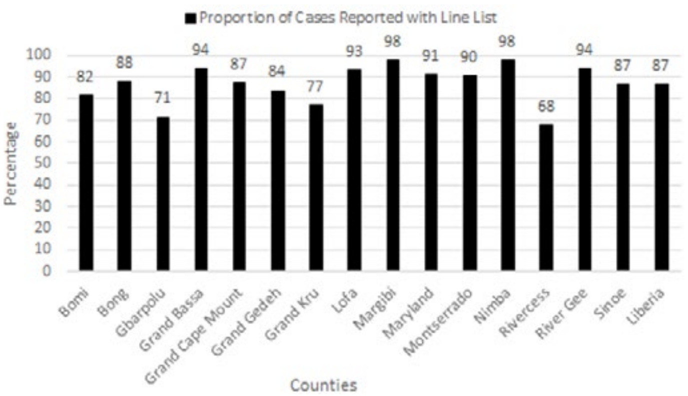

Figure 2: integrated diseases surveillance and response performance of proportion of cases reported with Line list, Liberia, 2017

partners during the monthly county surveillance meetings. The NPHIL produced 52 weekly bulletins and one semester bulletin of priority diseases and events in 2017. Some OICs mentioned that it was difficult to make regular graphs for the priority diseases in the HCFs.

Outbreak preparedness: after the EVD outbreak, the incidence management system was successfully reactivated during an outbreak of meningococcal disease in 2017 at both national and county level. The infection prevention and control (IPC) protocols were available at 82% of the HCFs supervised in 2017. At county level, there were county rapid response teams (CRRT) and at district level there were districts rapid response teams (DRRT), both trained during and after EVD outbreak. The lack of isolation and triage at the HCFs were some of the major challenges identified by OICs during the supervisions. In addition, they reported constant stock out of IPC materials and inadequate referral system.

Outbreak detection: the linelist of alerts and rumors from the community were available in 46% of the HCFs assessed in 2017. From January to December, 2017, the country detected suspected outbreaks of 18 different conditions (Table 2 and Table 3). From those conditions, cases of shigellosis, human rabies, cholera, Lassa fever, measles, rubella and meningococcal disease were confirmed by national and international labs (Table 2). Some conditions were confirmed clinically, with no lab tests performed (Table 3). All the suspected measles cases with results negative were tested for rubella and 315 positives cases were detected from all the regions. We identified some sporadic comprehensive outbreaks investigation reports at the national level received from the counties, especially for meningococcal disease, measles, lassa fever, skin diseases and cholera.

Outbreak response: according to the records reviewed, all the outbreaks detected in 2017 were on average investigated within 48 hours, accompanying initial investigation reports. The main outbreaks (measles, lassa fever and meningococcal disease) had regular situational reports from the counties and national level. The response of the outbreaks varied from local responses for the small outbreaks such as scabies, pertussis, shigellosis, to complete reactivation of incident management system (IMS) at the county and national level for outbreaks of meningococcal disease, lassa fever and measles. The meningococcal disease outbreak was responded with chemoprophylaxis (ciprofloxacin and ceftriaxone) among other measures, lassa fever was responded to with appropriate case management (treatment with ribavirin), contact tracing and isolation of the cases and measles campaigns and administration of vitamin A were performed to control the measles outbreaks. The other outbreaks were also controlled according to the situation with emphasis to health education, sanitation and hygiene, besides case management and immunization for vaccine preventable diseases like yellow fever.

Laboratory function: some laboratories with capacity to confirm EVD (RT-PCR, GeneXpert), Lassa fever, Yellow fever, acute watery diarrhea, acute bloody diarrhea and meningitis were installed at the national level and strategic counties from 2015 to 2017. The stool specimens were tested for poliomyelitis in Ivory Coast, while the yellow fever cases were confirmed in Senegal and lassa fever in Sierra Leone. The other conditions were confirmed in other countries based in previous negotiation. For instance, the rabies cases was confirmed in France and meningococcal disease had specimens tested in Atlanta, United States, France and South Africa. A total of 60 couriers from Riders-for-Health were transporting specimens from 302 HCFs across the country to the public health laboratories from January to June 2017. During the same period, a total of 1631 specimens were tested for 8 epidemic-prone diseases and conditions. The lab results were sent regularly by email of the county health teams (CHT) created specifically for lab results to be assessed by key CHT staff and partners. The frequent stock out of lab supplies including specimen collection materials, lack of fridge to store the specimen in one HCF and inadequate lab space in other HCF were the main challenge reported by OICs during the supervisions.

Data management and feedback: at the national level, the data were stored in excel sheet for IDSR data and DHIS2 for the monthly reportable diseases. All the bulletins produced by NPHIL were published at the MOH and NPHIL websites. A feedback power point presentation was conducted weekly by NPHIL to partners and stakeholders. From the national to county level, power point feedback on IDSR situation in Country and lab results were circulated through email weekly. There was no evidence of any feedback provided about the monthly reportable diseases at all levels. At the county level, the weekly IDSR supervisions were used to provide feedback from the county to district and facility level. Although VHF-Epi-info database was being used for EVD outbreak in a parallel surveillance system, later integrated into the HMIS (DHIS2) there is no documentation of other surveillance systems used before the implementation of IDSR. The OICs were not satisfied with feedback received, and because the issues from previous supervisions were rarely or never addressed.

Support functions

Trainings: in 2017, all the county, district and zonal surveillance officers were trained in IDSR and field epidemiology training program (FETP). In addition, different refresher IDSR trainings were conducted targeting all the health workers and stakeholders across the country. Nevertheless, during the 2017 assessment, only 46% of the IDSR focal persons from the facilities (OICs) were trained in IDSR in the past one year and 76% of the HCFs had at least one staff trained in swab collection. However, 84% of the facilities had community volunteers in the catchment areas trained in community based surveillance in the past one year. The IDSR training at all levels was supported by WHO, while other partners were involved also in IDSR training at the community level. The inadequate training of the HCF staff including the OICs was the most important challenge identified by a considerable number of OICs supervised. They mentioned the need of training of other staff including vaccinators, since the OICs is usually overwhelmed with other activities. Other solutions suggested were regular supportive supervisions, in-site mentoring and retain the trained staff in the HCF.

Supervisions: the IDSR supervisions were conducted regularly in Liberia where the HCFs should be supervised at least once per month. From September to November 2017, 50% of the HCFs were supervised, with the highest percentage (89%) in south western region and lowest percentage in the south eastern B (26%). On the other hand, 93% of all the HCFs received supervision feedback report from district/county in the past four weeks and 82% of the facilities conducted regularly supervisions to the community volunteers.

Resources: in 2016, WHO provided motorbikes, computers and printers to all the DSOs, CSOs and ZSOs and office equipment to all the district health teams (DHTs) across the country. Besides fuel, WHO also provided lubricants, spark plugs, spare parts for motorbikes and scratch cards for communication provided to all the districts every quarter. However, although 94% of the HCFs were supervised from September to November 2017, 42% had no adequate and functioning transport, including fuel, for surveillance activities. The inadequate resources to perform the surveillance activities at the facility level was one of the most important challenges raised by the OICs. They requested motorbikes (including maintenance), fuel support, phone and scratch cards for communication, and financial incentives to encourage the overwhelmed staff to perform surveillance activities. One OICs requested one more clinician to support the OIC since the clinic was operating with only two staff.

Standards and guidelines: although from 2015 to 2017, two versions of IDSR guidelines were produced in Liberia and distributed to all the HCFs, during our 2017 assessment 34% of the facilities had no IDSR guidelines available during our assessment. The standard operation procedures (SOPs) for dead body management was available in 74% of the facilities while the SOPs for sample collection, packaging, and storage for priority diseases were present in 76% of the HCFs. One of the OICs interviewed requested to be supplied with additional IDSR guidelines.

Coordination: from 2015 to 2016, all the IDSR activities in Liberia were coordinated by MOH and taken over by NPHIL after its creation in 2017. NPHIL is directly supported by MOH and partners including WHO and Center for Disease Control and Prevention. The DSOs who were identified, trained and assigned in 2016 were responsible for coordinating the IDSR activities at the district level, while the CSOs, who were previously part of the MOH system coordinated the IDSR at the County level. During the organizational stage of the NPHIL, the DSOs incentives were provided directly by WHO. However, when the payment was handed over to NPHIL, there was a temporary interruption of payment which led to dissatisfaction and temporary refusal of the DSOs and ZSOs to submit reports to the national level, although the surveillance activities never were interrupted.

Discussion

Our study shows that IDSR has been actively implemented in Liberia since 2015. Feedback to the counties and HCFs, including laboratory results using email, regular supervision to all the HCFs, the introduction of mobile phone applications for data collection and management and the electronic platform for AFP surveillance were some of the innovations observed during this period. The electronic surveillance is useful in reducing the time from detection to reporting of public health events, allowing a fast investigation and response [14]. Although the electronic surveillance was piloted in Liberia, a study conducted in Tanzania in 2012 [15] and Kenya in 2016 [16] demonstrated that the use of mobile phones for surveillance can dramatically improve the timeliness and completeness of the reports. The reestablishment of IDSR in Liberia utilized the existing health structure through integration of existing surveillance systems. This included establishment of a coordination mechanism to link various surveillance systems to create an integrated system, harmonization of data collection tools, procurement of standardized data storage; and storing data in a uniform database where could easily be accessed by users and policy makers. This integrated system is particularly important to address all the public health events notifiable under IHR (2005) [17]. However, Liberia was running a parallel system (HMIS) to report monthly other conditions together with the conditions reportable under IDSR, leading to data discrepancies. The same challenge was observed during an assessment conducted in Ethiopia [18] and was even worse in Tanzania in 1998, when five parallel surveillance systems lead to poor performance in all the IDSR functions [19].

The implementation of IDSR in Liberia guided the decision-making for public health action and contributed to the overall health sector goal of reducing morbidity and mortality due to preventable causes, exemplified by all the outbreaks suspected, confirmed and controlled quickly with law case fatality rate in 2017. However, although malaria was the most important cause of admission and deaths in Liberia, especially among children [12, 20], it was not part of IDSR. In other countries like Ghana [21] and Ethiopia [18], the use of malaria data obtained through IDSR lead to important decisions to reduce the morbidity and mortality of the illness. The resilience of surveillance system in Liberia was also contributed by the integration of the private HCFs into IDSR, considering that 38% (296/773) of the HCFs in Liberia were private, with 96% (285/296) of them reporting regularly to the surveillance system. Unlike Liberia, the integration of private facilities into surveillance system in other countries was a challenge, compromising the completeness of reporting [13]. Despite the temporary interruption in reporting by the DSOs and ZSOs verified in 2017 in Liberia, the completeness of reporting remained high in 97%, since the private facilities continued reporting and ZSOs from Montserrado were supported by other partners. However, it affected negatively the number of supervisions conducted to the HCFs, being 50% (384/773) from September to November, 2017, far from the 80% recommended in IDSR guidelines. The consistent high completeness and timeliness of reporting was also contributed by the availability of resources like computer, printers and means of transport provided by WHO at district and county level. However, the same resources still not available at facility level in Liberia. The lack of resources, including reporting forms verified in Nairobi [22] and Nigeria [23] compromised the submission of weekly reports and other IDSR functions in general.

Although all the HCFs in Liberia had IDSR focal person, the follow up trainings were poor, representing only 46% (178/384) of IDSR focal point trained in the past year due to attrition of the previously trained staff. This may lead to poor quality of reporting, difficulties to use the standard case definition (relying more in clinical judgment), poor data analysis skills and inadequate supervisions and feedback to the community level as demonstrated in Tanzania in 2002 [24]. Liberia also had not integrated yet into IDSR other components of IHR (2005) like animal, food poisoning, chemical poisoning and disaster in the same level as other countries [17]. Instead, those events were classified as cluster of events and deaths. The qualitative questions from IDSR supervision revealed that the health workers were not satisfied with their level of training in IDSR, besides the workload, poor feedback with the issues raised in the supervision not addressed before the following supervision and inadequate means of transport and communication. The same findings were observed in qualitative study conducted in Zambia in 2016 [25]. Our study had several potential limitations. There was no information available about the implementation of IDSR in Liberia before the EVD outbreak. In addition, after the re-introduction of IDSR in 2015, different supervision tools were used, making difficult to compare the progress of indicators over the years. The assessment was also done by people from the county (DSOs) and information biases are expected. The interviews with the OICs were not recorded and transcribed, making impossible to reproduce verbatim quotes in our analysis. Despite these limitations, our findings can reliably be used for decision making and documentation.

Conclusion

Liberia is facing the same challenges as other countries during the early stages of implementation of IDSR. However, the innovations were implemented in a short time. The surveillance system was resilient, despite the challenges. The resources are available at national, county and district level, but inadequate at the facility level. The supportive supervisions were conducted regularly but the health workers at facility level were not satisfied with the feedback provided to them. We recommend the government and partners to give attention to the HCFs, especially providing adequate resources and regular feedbacks.

What is known about this topic

- Integrated diseases surveillance and response is actually being implemented in several countries in Africa, including Liberia;
- Liberia adapted the integrated diseases surveillance and response (IDSR) in 2004 as a platform for implementation of International Health Regulation (IHR (2005));
- Liberia and other west african countries recognized late the Ebola virus diseases outbreak in 2013/2014 after several deaths being reported.

What this study adds

- Status of integrated disease surveillance and response implementation in Liberia to avoid deadly diseases outbreaks to be recognized late and avoid high cases fatality rate;
- Best practices on implementation of integrated diseases surveillance and response in Liberia after the Ebola virus diseases outbreak;
- Challenges faced by the country to implement the integrated diseases surveillance and response after the Ebola virus disease outbreak.

Competing interests

The authors declare no competing interest.

Authors' contributions

Thomas Nagbe and Jeremias Domingos Naiene: study design, data collection, data analysis, manuscript writing and submission. Julius Monday Rude, Nuha Mahmoud and Okeibunor Joseph Chukwudi and Soatiana Rajatonirina: data collection, data analysis and read critically the manuscript, provided the necessary corrections and approved for submission. Mohammed Kromah and Jeremy Sesay: data collection, data analysis, read critically the manuscript and approved for submission. Mary Stephen, Ambrose Talisuna, Ali Ahmed Yahaya: data collection, data analysis, read critically corrected the manuscript and approved for submission. Musoka Fallah, Tolbert Nyenswah, Bernice Dahn, Alex Gasasira: study design, data collection, data analysis, read critically and corrected the manuscript and approved for submission. Ibrahima Socé Fall: coordinated the overall manuscript writing, data collection and data analysis and approved the manuscript for final submission.

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Research

Risk communication during disease outbreak response in post-Ebola Liberia: experiences in Sinoe and Grand Kru counties

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Abstract

Introduction: lessons learned from the Ebola virus disease (EVD) outbreak enabled Liberia to develop a health plan for strengthening public health capacity against potential public health threats. risk communication is one of the core pillars that provide life-saving information and knowledge for the public to take preventive and proactive actions against public health threats. These were applied in response to the post-ebola meningococcal septicemia and meningitis outbreaks in Sinoe and Grand Kru counties. This paper documents risk communication experiences in these post-ebola outbreaks in Liberia.

Methods: risk Communication and health promotion strategies were deployed in developing response plans and promptly disseminating key messages to affected communities to mitigate the risks. Other strategies included engagement of community leaders, partnership with the media and dissemination of messages through the community radios, active monitoring community risk perceptions and compliance, rumor management, mobile stage and interpersonal communication (IPC) during the Meningococcal disease outbreaks in Sinoe and Grand Kru counties.

Results: in Sinoe, about 36,891 households or families in 10 health districts were reached through IPC and dialogue. Circulating rumors such as "Ebola" was the cause of deaths was timely and promptly mitigated. There was increased trust and adherence to health advice including prompt reporting of sick people to the nearest health facility in the two counties.

Conclusion: risk communication and health promotion encouraged community support and involvement in any response to public threats and events. No doubt, risk communication and health promotion play an important role in preparedness and response to public health emergencies.

Introduction

The magnitude and intensity of the 2014-2016 Ebola virus disease (EVD) outbreak in Liberia incapacitated the country's social, educational, and financial sectors. The health system was overwhelmed by the high case counts, inadequate isolation capacity, and staggering death toll among infected healthcare workers. By the end of the outbreak, a total of 9,862 confirmed, suspected, and probable EVD cases with 4,408 deaths had been registered [1]. The health system was ill-prepared, partly due to limited resources and weaknesses in the core competencies of the International Health Regulations (IHR) namely the ability to detect, prevent and respond to public health threats. Like most sectors within the health system, the 2014 outbreak of the ebola virus uncovered the multiple challenges and weaknesses within Liberia's Health Promotion Division (NHPD). As a result, initial efforts of the NHPD to respond to concerns of the general population were overwhelmed by rumors and distrust. Contributing to the rapid spread of transmission, the initial response to the EVD outbreak was characterized by high levels of public denial, misconceptions, misinformation and resistance at the community level. Findings from anthropological studies conducted during the outbreak provided additional insight into community perspectives of the disease and the response efforts [2, 3]. Many community members attributed their initial disbelief of ebola either to the clinical presentation of the disease, which had symptoms similar to common illnesses like malaria and cholera, or to supernatural causes. Additionally, several conspiracy theories were circulating and suggested that Ebola was a manmade disease or money-making scheme. Moreover, community members complained that government messages about Ebola were ambiguous and confusing e.g. calling for the sick people to go for the health facilities and yet the messages were informing the community that "Ebola kills and has no cure". While the media initially focused on debating on misuse of resources as opposed to promoting key messages diverting the response efforts, there was also poor coordination among partners which resulted in the dissemination of conflicting messages. Although community concerns were not captured to inform the messages and approaches initially, this was adjusted using results from the anthropological studies [3].

Wildly spreading rumors and misinformation about the virus also adversely affected response efforts. Some communities were reluctant to report sick loved ones and relatives for fear of being quarantined or taken to the Ebola treatment unit (ETUs). More deaths occurred at homes and secret burials were frequently practiced to avoid the government's cremation policy [2]. Hence, interrupting the transmission of the virus became complex. It became imperative to introduce risk communication as a sure way of providing real-time information and easily understood messages to the public about Ebola and of encouraging participation in the response efforts. In October 2014, Liberia's NHPD initiated its Ebola-related risk communication activities. Messaging prompted people to observe preventive measures including washing of hands with soap and water, not touching sick ones suspected of having the disease, allowing decent and safe burials, identifying sick people within the community, and calling the EVD hotline to pick up sick people from the community. Despite progress, the health promotion efforts continued to encounter misconceptions, doubts, and community resistance before Liberia was declared Ebola-free in May 2015 [4]. Three subsequent EVD outbreaks in Margibi and Montserrado counties during 2015 and 2016 provided the NHPD with additional opportunities to improve its health promotion response strategies.

Based on the lessons learned from the EVD outbreak in the West African Region, WHO/AFRO organized a three-day meeting in 2015 in Dakar, Senegal with the ultimate goal of strengthening national Risk Communication under the 2005 International Health Regulations (IHR) in each Ebola-affected country. Risk Communication stands out as a core element of the IHR to detect, report, and respond to any public health emergency [5]. WHO and CDC supported Liberia's capacity building and strengthening. WHO supported 55 master trainers as trainers of trainers (TOTs) from the National Health Promotion Division, County Health Promotion Focal persons and program managers; 75 media personnel, and 19 community health and health promotion focal persons from the counties. Additionally, in April 2017, the CDC trained 53 health promotion and community health focal persons and other central level staff in field module risk Communication [6-8] With this capacity, the NHPD was better positioned to respond swiftly during outbreaks. The health promotion focal persons from Sinoe, Grand Kru and other Counties were trained in social mobilization during the EVD outbreaks and gain a lot of experiences in providing messages to reduce fear and convince the communities to visit the health facilities [9]. However, the need of a risk communication strategies to address similar outbreaks in future was one of the lessons learnt during the EVD outbreak [10-16]. The post-EVD outbreaks in Sinoe and Grand Kru Counties were promptly addressed using the risk communication strategies, which was useful also to reduce the fear and enhance EVD surveillance during the flare ups in other counties [17]. However, there is a limited documentation of the levels of effectiveness of the risk communication strategies to provide lessons to other public health interventions within and outside Liberia. This paper thus documents the role of risk communication in response efforts during post-EVD outbreaks of meningococcal septicemia in Sinoe and meningitis in Grand Kru Counties.

Methods

Under the IHR, risk communication for public health emergencies includes the range of communication capacities required through the preparedness, response and recovery phases of a public health event to encourage informed decision-making, positive behavior change and the maintenance of trust. Risk communication outbreak responses for Sinoe and Grand Kru were mainly characterized by the practical application of lessons learnt from the Ebola outbreak with additional skills from the trainings conducted. The main risk communication methods used in Sinoe County Meningococcal Septicemia and the Grand Kru Meningitis outbreaks were centered around active community engagement of affected and surrounding communities through the development of messages, advocacy with local stakeholders, interpersonal communication , live radio talk shows in English and local languages (Kru and Sapo), and active monitoring and response to rumors. All responses were to promptly address community concerns, and link messages and actions to the desired practices that reduce the risk of transmission within the community. Key messages and materials informed by the risk assessment and community risk perceptions were developed and disseminated in the affected counties through appropriate channels to enable community members to identify risky practices and reduce the risks of transmission and spread of the disease within the community. Additionally, targeted community engagement strategy with key stakeholders including county authorities, chiefs and elders, and community leaders was useful to change community perceptions and myths and for them to solicit their support and participation in response efforts in the two counties. Regular updating of the coordination and community engagement pillars on community concerns and potential barriers to compliance and control measurers helped tailor the response strategies.

Sinoe county outbreak of meningococcal septicemia.

Description of outbreak: on tuesday, 25th April 2017, the Sinoe County Health Team (SCHT) notified the National Public Health Institute of Liberia (NPHIL) and the Ministry of Health (MoH) of a cluster of unexplained health events involving 14 cases with 9 deaths in Greenville City. According to the SCHT, cases presented with headache, diarrhea, mental confusion, weakness, vomiting and abdominal pain. Many of the cases reported onset of symptoms following attendance at a funeral event (wake, burial, repass) on the 21st and 22nd of April 2017. The disease was initially characterized by high case fatality and the need to disseminate information despite the uncertainty of the disease's causative agent (Table 1). Due to the magnitude of the outbreak, the NPHIL and the MoH deployed surge capacity with a team of six national experts providing technical support to the SCHT. The team establishment was based on call for national support in the areas of coordination, infection prevention and control, case management, dead body management, social mobilization/risk communication, and epidemiology. In view of the convolution of the outbreak, the national and county Incident Management Systems (IMS) were activated along with the district rapid response team (RRT) backed by the national technical support team. Needed resources including medical and non-medical supplies were mobilized. Strategic areas of focus for the investigation included social investigations (social epidemiology) and disease investigations (disease epidemiology including laboratory). The initial investigation sites included eight communities in the Greenville health district: Teah´s Town, Red Hill, Congo Town, Down Town, Johnston Street, Mississippi Street, PO-River, and Fish Town communities. Other communities visited during the investigation included Louisiana, Butwua Oil Plantation Company (BOPC) mining/plantation, and Dioh Town. Using the ring approach, the response team was able to identify all facilities used for treatment including public and private health facilities, traditional healing places and healers, and prayer homes. All neighboring counties were alerted and regular updates shared.

Table 1: chronology of the main events and activities implemented during the meningococcal disease outbreak, Sinoe County, Liberia, 2017	
Date	**Events and activities**
25 April 2017	Sinoe County Health Team (SCHT) notified the National Public Health Institute of Liberia (NPHIL) and the Ministry of Health (MoH) of a cluster of unexplained health events involving 14 cases with 9 deaths in Greenville City
25 April 2017	Activation of the incident management system at the County level
25 April – 23 June 2017	Community Engagement meetings with Religious leaders, Chiefs and Elders, Schools and youth groups
26 April - 26 June 2017	House to house awareness by mobilizers
26 April – 26 June 2017	Publicity awareness with PA system in moving Vehicle
29 April 2017	3 suspected cases self-reported to the main hospital (FJ Grante hospital) in Sinoe County
30 April 2017	Last case of the outbreak reported
3 May – 25 June 2017	Radio Talk shows
3 May 2017- 25 June 2017	Radio announcement with jingles
7 May 2017	Outbreak confirmed as meningoccocal disease
14 May 2017	County Level Advocacy Meeting
22 - 25 May 2017	District Advocacy Meetings
25 May 2017	Provision of chemoprofilaxis with ciprofloxacin and ceftraxone to the contacts without any community resistance reported

Grand Kru county outbreak of meningitis

Description of outbreak: on September 22, 2017, the Grand Kru County Health Team (GKCHT) reported three suspected cases of meningitis that were detected in Barclayville Health District. The index case was a 22-year-old female client who was admitted on September 7, 2017 but died September 9, 2017, two days after admission in the hospital. Burial was conducted by the patient's family member who did not observe the safe and dignified burial procedure. Meanwhile no other family member reported similar symptoms. On September 17, 2017, an 18-year-old male was confirmed of meningitis in the Zoloken community in Barclayville Health District, Grand Kru. In all, there were five other cases including one confirmed, 3 suspected and one death recorded. The cases presented with common signs and symptoms like headache, stiff neck, altered level consciousness, fever, inability to talk, etc. Blood samples were collected for all three of the cases and transported to the Nation Reference Laboratory in Margibi County. However, only one case was confirmed meningitis positive. Fifty contacts were line-listed including 17 health workers.

Results

Mechanisms of risk communication: during the outbreak intervention, the County IMS was activated to coordinate the response activities. Various risk communication approaches were deployed to respond to the cluster of deaths in the county. Risk assessment, understanding community risk perceptions, advocacy meetings, targeted community engagements with influencers, inter-personal communication, and media engagements were conducted to seek communities' support and participation in the response. The risk communication team engaged community and religious leaders to create awareness, dispel rumors and overcome community resistance. Information was provided to the public through radio talk shows and street broadcasters, encouraging the community to identify and report persons with specific signs and symptoms in the community to health facilities. A town hall meeting was convened to solicit information from community members and for the county superintendent and health officials to answer questions from the public. Properly trained social mobilizers worked jointly with surveillance officers during active case search, facilitating entry and surveillance activities in the community. Consequently, community leaders and members received real time information on the cluster of deaths and they supported preventive measures to address the health problem. Sinoe County has two major radio stations situated in the capital Greenville: the Liberia Broadcasting System (LBS) and the Sinoe County Community Radio Station (SCCRS). These stations cover all of the ten health districts. However, both radio stations had technical difficulties during the first week of the response. The mobile stage and the SCCRS were instrumental in disseminating the meningitis prevention messages. The mobile stage consisted of a pick-up truck on which loud speakers were mounted. The truck moved in and around Greenville City and aired key messages on hand washing, the importance of reporting anyone showing signs and symptoms to community leaders or health authorities, and prevention messages on meningitis. This was reinforced by radio talk shows that included discussions of these messages. Local community radio stations also aired similar messages as public service announcements. The LBS, the mobile stage and the SCHT's daily Situational Report were the basic media outlets used in the response, especially in providing real time information and addressing rumours.

Content of risk communication messages: key messages were tailored to the stage of the response. These included emphasizing importance of good hygiene practices such as hand washing, avoiding shaking of hands and public gatherings, and the need to report to a health facility upon onset of any symptoms. Due to the uncertainty of the cause of death, the initial risk communication messages focused on reassuring the public that the blood samples tested negative for Ebola. The main content of the messages was for communities to report any usual deaths to the health facilities. Due to the breakdown of the only functional radio station in the county during first week of the response, a mobile stage was used to broadcast the message and the negative Ebola laboratory results to the 10 hotspots and 14 surrounding communities in Greenville and in the Butwua and Kpan Districts. Moreover, materials such as hand washing posters and brochures were used during community engagement meetings.

Staffing: risk communication response activities were led by the county health promotion focal person. Additional technical support was provided by the NHPD, WHO, CDC and UNICEF. The Risk Communication Focal Person was on the ground working with the Sinoe county social mobilization pillar. The SCHT with support from the MOH at the central level and UNICEF deployed community health volunteers who conducted house-to-house awareness in districts and at the community level. These activities were coordinated by the county health promotion focal person and the community health focal persons.

Outcomes of the risk communication strategy: through the joint efforts of all thematic response pillars, county authorities and the national rapid response team, a total of 27 cases with 10 deaths were reported in Sinoe County and four epidemiologically-linked cases, including three deaths, were reported in Montserrado and Grand Bassa counties. Cases were managed, and the outbreak contained only among those who attended the funeral. Rumors that Ebola was the cause the death that circulated were timely and promptly mitigated. About 36,891 households or families were reached through interpersonal communication; this led to increased trust and adherence including prompt reporting of sick people to the nearest health facility (Table 2).

Table 2: main outcomes of the risk communication and social mobilization activities implemented during the meningococcal disease outbreak, Sinoe County, Liberia, 2017	
Unit	**Total Number**
Estimated household/families reached through IPC	36891
Estimated children reached through house to house mobilization	15229
Estimated Women reached through house to house visits	19323
Total community meetings held	821
Estimated homes hand washing stations reactivated	36891

Description of risk communication strategy: similar to the Sinoe outbreak, the GKCHT activated the County IMS and key response pillars: coordination, surveillance, risk communication/ social mobilization, and infection prevention and control. The risk communication plan was produced and implemented quickly to develop and disseminate key messages on meningitis in all the districts through engagement meetings with key stakeholders in communities and schools. Meningitis messages including the factsheets and audios messages about the disease were disseminated to the county in less than 24 hours. The Voice of Grand Kru, a local community radio station in Grand Kru supported by UNICEF was used to air messages. The county health promotion focal person led the risk communication team along with community health focal person. Other channels used to share information were through community engagement meetings, interpersonal communication by community health assistants and local leaders.

Content of risk communication messages: using lessons learned from previous outbreaks including the meningococcal septicemia outbreak in Sinoe, stakeholders' advocacy, community engagement meetings in schools and town halls, radio talk shows, airing of jingles were the medium through which messages were disseminated during the Grand Kru Meningitis cases. Message content informed the at-risk population about the disease, the signs and symptoms, and importance of early reporting to the nearest health facilities.

Staffing: prior to the outbreak, meningitis messages were developed by the national a message coordination body at the national level. Through the chair of the Social Mobilization/Risk Communication Pillar, messages were promptly disseminated from the national level to the county. Messages were promptly disseminated because of the timely sharing of the laboratory results and availability of the messages prior to the cases confirmation. The County risk Communication Pillar team which was led by the Health Promotion Focal Person along with the Community Health Focal Person oversaw the communication aspect of the response. Community Health Assistants were responsible for house-to-house awareness. The voice of Grand Kru, the local radio station, played a key role in disseminating the meningitis messages. Live radio talk shows were conducted by member of the county health team and stakeholders.

Outcomes of risk communication strategy: as the result of the robust approach and coordination between major response pillars and with the national and county coordination mechanism, the outbreak was timely interrupted. As of the first three cases reported, no additional cases were detected among 50 line-listed contacts. The community members in the three communities were well-informed about the disease and took preventive measures. The voice of Grand Kru was the main source of information sharing during the response activities. The total summary of the population reached remained a major challenge due to a gap in national monitoring. At least 50 contacts including 17 health care workers from the Sass Town Health Center and Rally Town Hospital were line- listed. Of the total 5 cases suspected, only 1 was confirmed meningitis positive. There was only one death and no secondary transmission was reported among cases. Risk communication played a significant role during and after the response. Community members and elders helped in identifying people connected with the health problems and persons infected or suspected of being infected sought medical attention at various health centers in the county. Indeed "local solutions helped solve local problems!" Risk communication increased the level of trust in the health system contrary to the perceptions exhibited during the EVD outbreak.

Discussion

Overall, risk communication has played a key role in post-EVD recovery in Liberia. Successful strategies that were deployed during the EVD response in West Africa [16, 18] have been repeatedly applied to non-EVD outbreak settings. As was seen towards the end of the initial EVD outbreak in Liberia and again during subsequent flare-ups, key meningitis prevention messages and materials were developed and disseminated during and after the outbreaks in Sinoe and Grand Kru Counties. Community members who were exposed to these messages got a clear understanding of the disease that affected them. Other risk communication milestones included community dialogues and interpersonal communication with key stakeholders including at-risk segments of communities where issues were discussed and consensus reached on key action plan/ practices to reduce the risk. Community members actively assisted in identifying suspected cases and reporting them to health authorities while they reactivated home hand washing stations. The dissemination of the meningitis prevention messages through different channels like radio health talks shows and the mobile stage also buttressed the response efforts in the two counties. This helped to quickly address rumors and misinformation (Sinoe and Grand Kru Health teams personal communication). The risk communication strategies were effective to control other outbreaks during the late stage and after EVD outbreak in other counties of Liberia as well, with example of Lassa fever outbreak in 2016 when the communities had lack of knowledge of the disease in the beginning of the outbreak [19].

The outbreaks in Sinoe and Grand Kru Counties provided important lessons regarding the factors that can either hinder or motivate community members' willingness to adhere to risk communication messages during an outbreak. In Sinoe, information regarding the cause of the health emergency was initially confusing and, in some cases, contradictory. Initially, the cause of the unexplained illnesses and cluster deaths were reported as "probable meningitis". The public was subsequently informed that the cause of the deaths and illnesses was meningitis. Consequently, the public was confused and skeptical about the prevailing health problem until it was officially confirmed as meningococcal septicemia and messages clarified thereafter [20]. Best practices observed during the response involved community leaders and health workers collaboratively addressing problems. Community leaders and key stakeholders all worked together as a team with one goal in mind: to mitigate the health problems that affected them. Prompt response with key messages helped to respond to the problems. In this context, risk communication using appropriate messages, and the airing of same, community engagement and addressing community concerns, rumors and misinformation should form part of future emergency response. There were several limitations to the outbreak response that are important to mention. The dissemination of information about the outbreak in Sinoe County took some time and even with the information people did not and still do not know the actual cause of the reported meningococcal septicemia. Hence, in Sinoe County, it was difficult to convey the appropriate message to the public. However, in Grand Kru, where the initial case was a confirmed case of meningitis, the information about the disease and how to prevent additional cases was clear from the outset.

Lessons learned: early confirmation of a disease outbreak helps to provide a quick and coordinated response. However, if details about the outbreak are unclear, it brings about distrust and uncertainly. In Sinoe county, the cause of the cluster of deaths was not immediately established. It was reported that the health problem in Sinoe was a probable meningitis but outside of the case definition of meningitis. Later, it was indicated that the cluster of deaths was attributed to meningococcal septicemia, thus creating doubts and misinformation in the minds of people. The risk communication response was negatively affected because the evidence for the source of the health problem was unclear. However, in Grand Kru, the response was timely because it was confirmed from the outset that the disease was meningitis. The health promotion team responded timely by disseminating meningitis messages in less than 24 hours. This swift response helped community members to take actions in protecting themselves and their families which resulted in the prompt interruption of the outbreak. Additionally, because both of the health promotion focal persons in the two affected counties were trained in risk communication, they were in a better position to draw up a plan and work with the community to prevent the disease and interrupt the transmission. Partners' support also helped to quickly respond to the outbreak in a timely manner. Experience from the two outbreaks underscore how critical it is that risk communication plans incorporate the different phases of a response to ensure adequate preparedness and response. These include before the outbreak based on forecasts, during the alert phase leading to the outbreak to enhance control, and after the outbreak to ensure a clear exit strategy and promoting community resilience.

Conclusion

Risk communication and health promotion strategies form an integral part of any public health response. They provide life-saving information to people in affected communities for proactive actions to protect themselves. Lessons learned from the Ebola and post-Ebola responses clearly showed that health promotion and risk communication strategies were useful in developing and disseminating key messages, engaging communities, and managing rumors so that people can take informed decisions to mitigate the effects of public health threats. Going forward, it is important to incorporate culturally-appropriate health promotion and risk communication strategies in our preparedness and response efforts during emergencies and non-emergencies. This will provide the basis for an effective communication to the public at all times for better outcomes.

What is known about this topic

- Liberia introduced and implemented successfully the risk communication strategies during the Ebola virus disease outbreak.

What this study adds

- How the counties in are using the risk communication strategies after the Ebola virus diseases outbreak;
- Best practices on implementation of risk communication strategies in Liberia after the Ebola virus diseases outbreak;
- Challenges faced by the country to implement the risk communication strategies after the Ebola virus disease outbreak.

Competing interests

The authors declare no competing interest.

Authors' contributions

John Sumo, Geraldine George for the conception and design, acquisition of data, analysis and interpretation of data, drafting the article and final approval of the version to be published. Vera Weah for an acquisition of data, analysis and interpretation of data, revision of the article critically for important intellectual content and final approval of the version to be published. Laura Skrip, Julius Monday Rude, Peter Clement, Jeremias Naiene, Luwaga Liliane for an analysis and interpretation of data, revision of the article critically for important intellectual content and final approval of the version to be published. Okeibunor Joseph Chukwudi, Ambrose Talisuna, Ali Ahmed Yahaya, Soatiana Rajatonirina, Musoka Fallah, Tolbert Nyenswah, Bernice Dahn, Alex Gasasira, Ibrahima Socé Fall for the conception and design, analysis and interpretation of data, revision of the article critically for important intellectual content and final approval of the version to be published. All authors have read and agreed to the final version of this manuscript.

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Research

Strengthening immunization service delivery post Ebola virus disease (EVD) outbreak in Liberia 2015-2017

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Abstract

Introduction: the Ebola virus disease (EVD) outbreak in Liberia from 2014-2015 setback the already fragile health system which was recovering from the effects of civil unrest. This led to significant decline in immunization coverage and key polio free certification indicators. The Liberia investment plan was developed to restore immunization service delivery and overall health system.

Methods: we conducted a desk review to summarize performance of immunization coverage, polio eradication, measles control, new vaccines and technologies. Data sources include program reports, scientific and grey literature, District Health Information System (DHIS2), Integrated Diseases Surveillance and Response (IDSR) database, auto visual AFP detection and reporting (AVADAR) and ONA Servers. Data analysis was done using Microsoft excel spreadsheets, ONA software and Arc GIS.

Results: there was a 36% increase in national coverage for Penta 3 in 2017 compared to 2014 from WUENIC data. Penta 3 dropout rate reduced by 2.5 fold from 15.3% in 2016 to 6.4% in 2017; while MCV1 coverage improved by 23% from 64% in 2015 to 87% in 2017. There was a rebound of non-polio AFP rate (NPAFP) rate from 1.2 in 2015 to 4.3 in 2017. Furthermore, there was a 2-fold increase in the number of AFP cases receiving 3 or more doses of OPV from 36% in 2015 to 61% in 2017.

Conclusion: Liberia demonstrated strong rebound of immunization services following the largest and most devastating EVD outbreak in West Africa in 2014 - 2015. Immunization coverage improved and dropout rates reduced. However, there are still opportunities for improvement in the immunization program both at national and sub-national levels.

Introduction

When implemented under optimal conditions, immunization is one of the most successful and cost-effective health interventions against vaccine preventable diseases [1] saving an estimated 2-3 million lives annually around the world [1, 2]. Such success has been largely attributed to the launching of the expanded program on immunization (EPI) by the World Health Organization in 1974 with the aim to reduce morbidity and mortality associated with six major causes of death among children [1, 2]. Immunized children can lead to healthier and more productive lives [1, 3] and extending vaccination schemes to adolescents and adults can propagate these advantages through the life course [3, 4]. The global vaccine action plan 2011-2020 (GVAP) was designed with a vision for the decade of vaccines (DoV), to eradicate, eliminate or control serious, life-threatening or debilitating vaccine preventable diseases [4, 5]. Liberia has been committed to implementing universal immunization coverage through the GVAP to achieve the goal of a DoV. Despite a decade-long civil war that decimated health infrastructure, institutions and overall economy, the Ministry of Health (MOH) made steady efforts to revitalize the health system. The immunization program was strengthened with marked increases in coverage and immunity [6-8]. The 2014-2015 outbreak of Ebola virus disease (EVD) set back an already fragile health system that was recovering from the civil unrest. During the EVD outbreak, less than of 70% of health facilities were open and universally demand for health services was low due to fear and distrust in the health system. The Government of Liberia (GOL) declared a state of emergency to control the wide spreading EVD outbreak [9]. Subsequently, all planned routine immunization activities such as outreach, supplemental immunization activities (SIAs), the Human Papilloma Vaccine (HPV) demonstration project, and polio vaccination campaigns, among others, were paused [6-8]. These were in accordance to the guidance for immunization programs in the african region in the context of Ebola [10]. On the same note, the MOH could not implement and monitor the annual EPI work-plans, as all attention, including deployment of human resources were refocused to control the outbreak. Similarly, VPDs surveillance including specimen transportation by DHL was neglected at the height of the EVD outbreak. Thus, Penta-3 immunization coverage decreased by 26%, from 76% in 2013 to 50% in 2014 while, measles containing vaccine (MCV) coverage declined from 74% in 2013 to 58% in 2014 [11]. Simultaneously, there was a significant drop in the Non-polio AFP rate (population under 15 years) from 2.9/ 100,000 in 2013 to 1.2 /100,000 in 2015 (IDSR Database), well below polio free certification levels. Guinea and Sierra Leone encountered similar decline in immunization service delivery [12, 13]. Due to disruptions of health service provision, approximately 20, 000 children were unvaccinated on a monthly basis during the EVD outbreak, contributing to about 1.5 million unvaccinated children over an 18-month period [12]. Post EVD, the Liberia investment plan for rebuilding resilient health systems 2015-2021 and the immunization recovery plan for Liberia were developed with the aim to restore the immunization service delivery and overall health system. The introduction and piloting of new vaccines, technologies and innovations to strengthen quality health service delivery were also integral to the investment plan [6-8]. This paper aims to describe Liberia immunization program performance following EVD outbreak in 2014-2015, summarizing program management, activities and new vaccines & technologies implemented to strengthen EPI program, highlighting challenges and suggest recommendations for improvement plans to consolidate on progress made.

Methods

We conducted a desk review to summarize key activities conducted to restore immunization service delivery based on the strategic goals of the GVAP 2011-2020 namely: vaccine coverage targets at country and district levels, polio eradication, measles and MNT elimination, introduction of new vaccines and technologies (Table 1).

Study setting: Liberia is a tropical country in West Africa with an estimated population of about 4.1 million people, annual growth rate of 2.1%, total land area of 111,370 km2, and is bordered by Sierra Leone in the west, Cote d'Ivoire in the East, Guinea in the North and the Atlantic Ocean in the South. There are 15 counties (equivalent to WHO districts) and 91 health districts (sub-districts). It has 570 health facilities delivering EPI services across the 15 counties. The EPI manager leads the program with team leads for immunization, VPD surveillance, SIA, Logistics and cold chain. Child Survival Focal Person (CSFPs) at county and district levels manage the program at the levels and supervises the vaccinators at the health facilities.

Table 1: indicator description and target of the Polio eradication used in Liberia

Indicators	Description	Target	Comments
Penta 3 Coverage	Percentage of target children (< 1 year) receiving Penta 3 vaccine per year for routine immunization	80%	The national target was reset to 75% in 2015 following EVD outbreak. However, it will steadily increase to GVAP target of 95% by 2020
Penta 3 Dropout rate	Difference between Penta 1 and Penta 3 expressed as a rate	<=10%	
Polio coverage	An objective measure of SIA quality that can be used to guide improvements to reach more children by enabling corrective action both during SIAs using independent monitors	95%	
Polio Lots Quality Assurance Sampling (LQAS) Survey	A random sampling methodology as a method of quality control	< 3 out 60 missed children per Lot	
Measles SIA coverage	Percentage of target children (<5years) receiving Measles vaccine during SIA	95%	
Non-Polio AFP rate	Measures the sensitivity of AFP surveillance system	2/100, 000 pop. < 15 years	
AFP stool Adequacy	Measures the completeness of case investigation and quality of AFP stool specimen for laboratory testing	80%	

Data sources: data sources included immunization program evaluation and joint appraisal reports, program audits, technical reports, weekly and monthly EPI and VPD surveillance bulletins, quarterly EPI review meeting reports, meeting minutes, scientific literature, and literature. We also sourced data from DHIS2 database, IDSR database, auto visual AFP detection and reporting (AVADAR) and ONA Servers. Surveillance data were collected using the open data kit (ODK) mobile data application.

Data analysis: data on programs and vaccine uptake were evaluated for the period of 2015-2017 to show the impact of post-EVD implementation of the Liberia investment plan and immunization recovery plan. Frequencies and percentages were calculated to describe trends in coverage over time and geographic location. Data analysis for the ISS checklist was automatically performed in the ONA servers or exported to Microsoft Excel for further analysis. ArcGIS was used to develop geospatial and temporal distribution of data, including proximity analysis. We triangulated administrative data, independent monitoring data, LQAS survey data and WUENIC to compare outcomes and inform further analysis.

Results

Routine immunization

The development of immunization recovery plan post EVD in 2015, the revision and implementation of routine immunization micro plans based on principles of RED/REC and the implementation of urban immunization strategy in Montserrado County to reach urban slums and underserved population were the main activities to increase the access to the immunization services. As part of capacity building of the vaccinators, Immunization in Practice (IIP) training was conducted for health workers, refresher trainings, on-the-job training and mentorship for vaccination teams. The improvement of supply chain was done though the completion of the national vaccine store at Caldwell, Montserrado and two regional cold rooms in Grand Gedeh and Bong Counties. The optimization of the cold chain equipment and recruitment and training of 15 county supply chain officers were also part of the strategy. As part of the management of the program, besides development of the comprehensive multi year plan (cYMP) 2016-2020, the budget allocation was increased from $50, 000 USD in 2015 to $650, 000 USD in 2016. Capacity building for national teams was done through trainings and workshops. The country introduced electronic supervision tools such as electronic integrated supportive Supervision (ISS) and electronic surveillance (eSurv) checklists via open data kit (ODK) and WHO AFRO ONA servers and enhanced community involvement through advocacy meetings, social mobilization, deepened community engagement. In addition, technical Working Group Meetings, supportive Supervisions and quarterly EPI review meetings were conducted besides the development and dissemination of information products such Monthly EPI bulletins, VPD surveillance updates.

Polio eradication

The program working with GPEI partners developed the Brazzaville Initiative (B.I.) to re-invigorate polio eradication activities following

EVD outbreak control. The B.I. followed a mid-term review of the GPEI strategic plan in mid-2015 recommending strengthening AFP surveillance and containment activities, improving the quality of immunization campaigns and building national capacity to respond to outbreaks. The national polio committee prepared and presented the annual national polio update for 2016 following the EVD outbreak control at the ARCC annual certification meeting in Malabo, Equatorial Guinea in 2017, which was accepted. Active case search for AFP and stool transport for laboratory confirmation in Abidjan via DH was re-established In addition, OPV SWICTH was conducted in 2016 and IPV introduced into routine immunization in 2017. GAP 1 a and b were completed in 2016.

Disease control programs

The country conducted a catch up Measles SIAs targeting children 6-59 months in May 2015 and strengthened measles surveillance within the integrated disease surveillance response (IDSR) strategy. The analysis of low yellow fever EPI coverage in 3 counties: Grand Bassa, Rivercess, and Montserrado were conducted and improvement plans developed.

New vaccines and technologies

The country introduced new vaccines such Rota vaccine, IPV and HPV Demo Project. Mobile data collection tools and GIS technologies, namely open data kit (ODK), ONA and AVADAR GIS software was also introduced.

Outcome results

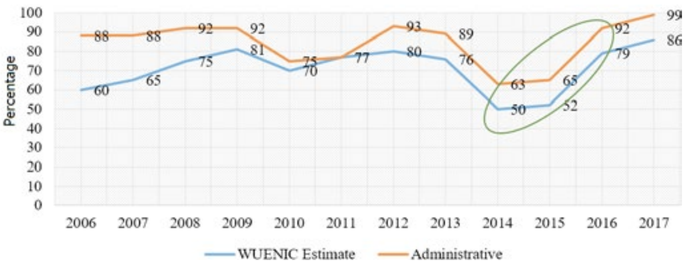

Figure 1: trends of Penta 3 coverage from 2006 to 2017, Liberia

Table 2: Penta 3 dropout rate (DOR) at national and sub-national levels from 2015 to 2017, Liberia

County	Penta 3 DOR 2015	Penta 3 DOR 2016	Penta 3 DOR 2017
Bomi	16.50%	26.10%	10.40%
Bong	9.10%	7.00%	4.60%
Gbarpolu	10.70%	6.90%	6.10%
Grand Bassa	22.70%	22.00%	15.10%
Grand Cape Mount	19.90%	15.40%	9.20%
Grand Gedeh	8.10%	1.10%	-1.10%
Grand Kru	22.80%	19.50%	8.00%
Lofa	6.20%	1.50%	9.10%
Margibi	24.80%	11.40%	10.60%
Maryland	13.80%	7.60%	7.30%
Montserrado	14.30%	11.20%	4.00%
Nimba	20.50%	8.50%	1.30%
River Gee	19.80%	8.70%	-9.00%
Rivercess	14.30%	11.60%	7.10%
Sinoe	10.00%	7.30%	2.30%
Liberia	15.30%	10.70%	5.50%

Routine immunization of Penta 3: there was a 34% increase in immunization coverage for Penta 3 from 52% in 2015 to 86% in 2017 (WUENIC 2017) (Figure 1). The trends for both administrative coverage and WUENIC follow similar pattern but there are discrepancies between coverage rates reported by both administrative and WUENIC reports. However, the absolute number of children 0-11 months vaccinated with Penta 3 in 2017 was 165, 972, an 11% increase in number of vaccinated children from 150, 231 in 2016 (DHIS2 database). Table 2 shows that at the national level, Penta 3 dropout rate in Liberia reduced approximately 3 fold from 15.3% in 2015 to 5.5% in 2017. In 2015, 80% of Counties had dropout rates above 10% compared to 20% of counties by 2017. In 2017, Grand Gedeh and River Gee Counties had negative dropout rates. However, Grand Kru, Lofa, Margibi Counties had dropout rates close to 10%, although this was lower than it had been for Grand Kru and Margibi in 2015. Grand Bassa and Bomi counties consistently had dropout rates above 10% for the period under review. Further analysis shows that Grand Cape Mount, Grand Gedeh, Grand Kru, Margibi, Montserrado, Nimba, River Gee, Rivercess and Sinoe counties had two-fold reduction in dropout rates from 2015 to 2017.

Polio eradication: there was a significant improvement in AFP surveillance indicators with a rebound of non-polio AFP rate (NPAFP) rate from 1.2 in 2015 to 3.7 in 2016. As of Epi Week 52, 2017, the NPAFP rate was 4.3. The stool adequacy rate also improved from 79% in 2016 to 82% as of Epi Week 52, 2017, meeting the global target of 80%. Furthermore, there was 2 fold increase in the number of OPV doses received among the AFP cases from 36% in 2015 to 61% in 2017. However, 20% (32/168) of the cases reported unknown number of OPV doses received. The LQAS survey results showed that a total of 10/15 (67%) of Lots were accepted in RD3 compared to 9/15 (60%) of Lots RD1 of Polio campaign in 2017. Only 0.1% Lot were rejected at < 80% in RD3 campaign compared to 33% in RD1 campaign 2017. However, Maryland, Margibi and Sinoe counties (Lots) were consistently rejected in the LQAS surveys conducted in 3 round of polio campaigns in 2017 (Table 3). IM assessment for Polio campaigns showed that 3/3 (100%) of the campaigns in 2017 and 2016, had estimated coverage above 95% (less than 5% of target children missed) compared 0% of the same indicator in 2015. In 2016, IM results of all four rounds in 2016 and 2017 showed that less than 5% of children were missed during the polio campaigns, converging with administrative data for the national level (Table 4).

Table 3: showing LQAS survey results from RD1- RD4 Polio campaigns, 2017 by County, Liberia

County	LQAS Feb 2017	LQAS Mar 2017	LQAS Nov 2017	LQAS Dec 2017
Bomi	Accepted	Accepted	Rejected	NA
Bong	Accepted	Accepted	Accepted	NA
Gbarpolu	Accepted	Accepted	Accepted	NA
Grand Bassa	Accepted	Accepted	Accepted	NA
Grand Cape Mount	Accepted	Accepted	Accepted	Rejected
Grand Gedeh	Accepted	Rejected	Accepted	Accepted
Grand Kru	Rejected	Accepted	Accepted	NA
Lofa	Rejected	Accepted	Accepted	Rejected
Margibi	Accepted	Rejected	Rejected	Accepted
Maryland	Rejected	Rejected	Rejected	Rejected
Montserrado	Accepted	Rejected	Accepted	Accepted
Nimba	Rejected	Accepted	Accepted	Rejected
Rivercess	Rejected	Accepted	Accepted	Accepted
River-Gee	Accepted	Accepted	Rejected	NA
Sinoe	Rejected	Rejected	Rejected	NA

Data source (WHO Liberia database and WHO AFRO ONA Server)

Table 4: administrative coverage and Independent Monitoring (IM) results for Polio campaigns in 2016 and 2017, Liberia

	2016		2017	
Polio SIA Round	**Administrative Coverage**	**Independent Monitoring**	**Administrative Coverage**	**Independent Monitoring**
RD 1	96.60%	95.20%	99%	97.4%
RD 2	95.20%	95.80%	99%	97.4%
RD 3	96.00%	96.40%	96.4%	97.7%
RD 4	99.90%	96.60%		

Data source: MOH administrative database and WHO IM database

Measles control: Figure 2 shows that MCV1 coverage improved by 23% from 64% in 2015 to 87% in 2017 based on WUENIC 2017 data. Furthermore, Table 5 also shows that in 2015, the post measles campaign coverage survey at the national level was 73.1% by vaccination card and verbal history while the coverage of 90.4% by verbal history alone. Only 3/15 (20%) counties had vaccination coverage above 90%. However, 11/15 (73%) of counties achieved coverage above 90% when evaluated by verbal history alone. The 3 most populated counties Lofa, Nimba, Montserrado, had coverages below 65% when assessed by vaccination card alone. A significant number of suspected measles cases were reported in Liberia in 2017. Of the reported cases, 17% (317/ 1818) were laboratory confirmed, 47% (858/ 1818) tested negative for measles. Of the 814 discarded measles cases, 40% (347/ 858) tested positive for rubella. The pie chart shows that 29% of confirmed measles cases during the review period received MCV1. A significant number (56%) of the reported cases had unknown vaccination status. As of Epi week 52, 2017, highly populated counties (Nimba, Bong and Montserrado) accounted for most measles outbreaks in the country. Nimba and Bong also share common borders with neighbouring countries such as Guinea and Cote d'Ivoire. Montserrado County accounts for 1/3 of the country population, with urban slums and population migration.

Yellow fever control: there was significant improvement in yellow fever vaccine (YF) coverage in 2017 which was 84%. The YF vaccine coverage for routine immunization was below target levels from 2010 up to 2016 (Figure 3). Disaggregated data by county shows that 60% (9/15) of counties met the national coverage target in 2017. Only 47% (7/15) met the national target in 2016 and 2017. Grand Cape Mount, Grand Gedeh, Maryland and River Gee counties consistently had lower coverage from 2015 to 2017.

Table 5: showing results of measles coverage survey 2015		
County	**Coverage by vaccination card (%)**	**Coverage by verbal history alone (%)**
Grand Kru	99.4	99.2
Grand Gedeh	95.4	99.3
River Gee	92.6	97.6
Bong	82.8	95.5
Margibi	80.4	94.8
Rivercess	81.1	94.2
Sinoe	76.5	94.4
Grand Bassa	76.7	93.1
Monrovia	77.3	90.7
Maryland	74.1	90.7
Bomi	69	89.9
Nimba	61.9	90.3
Lofa	58.3	87.1
Montserrado	43	79.8
Grand Cape Mount	43.5	72.4
Total	**73.1**	**90.4**
Data source: Liberia Post Measles Campaign coverage survey 2015		

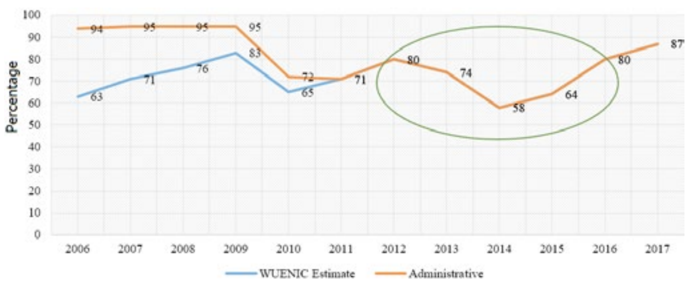

Figure 2: graph showing trends of MCV1 coverage 2006 to 2017

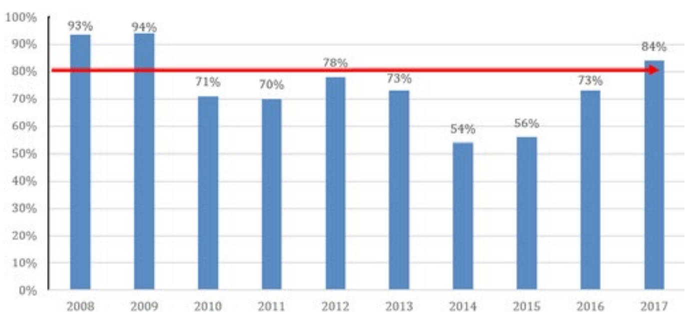

Figure 3: yellow fever vaccination coverage by year from 2008- 2017, Liberia (Data Source WUENIC 2017 and Admin (2017))

Discussion

Our study shows that IDSR has been actively implemented in Liberia since 2015. Feedback to the counties and HCFs, including laboratory results using email, regular supervision to all the HCFs, the introduction of mobile phone applications for data collection and management and the electronic platform for AFP surveillance were some of the innovations observed during this period. The electronic surveillance is useful in reducing the time from detection to reporting of public health events, allowing a fast investigation and response [14]. Although the electronic surveillance was piloted in Liberia, a study conducted in Tanzania in 2012 [15] and Kenya in 2016 [16] demonstrated that the use of mobile phones for surveillance can dramatically improve the timeliness and completeness of the reports. The reestablishment of IDSR in Liberia utilized the existing health structure through integration of existing surveillance systems. This included establishment of a coordination mechanism to link various surveillance systems to create an integrated system, harmonization of data collection tools, procurement of standardized data storage; and storing data in a uniform database where could easily be accessed by users and policy makers. This integrated system is particularly important to address all the public health events notifiable under IHR (2005) [17]. However, Liberia was running a parallel system (HMIS) to report monthly other conditions together with the conditions reportable under IDSR, leading to data discrepancies. The same challenge was observed during an assessment conducted in Ethiopia [18] and was even worse in Tanzania in 1998, when five parallel surveillance systems lead to poor performance in all the IDSR functions [19].

The implementation of IDSR in Liberia guided the decision-making for public health action and contributed to the overall health sector goal of reducing morbidity and mortality due to preventable causes, exemplified by all the outbreaks suspected, confirmed and controlled quickly with law case fatality rate in 2017. However, although malaria was the most important cause of admission and deaths in Liberia, especially among children [12, 20], it was not part of IDSR. In other countries like Ghana [21] and Ethiopia [18], the use of malaria data obtained through IDSR lead to important decisions to reduce the morbidity and mortality of the illness. The resilience of surveillance system in Liberia was also contributed by the integration of the private HCFs into IDSR, considering that 38% (296/773) of the HCFs in Liberia were private, with 96% (285/296) of them reporting regularly to the surveillance system. Unlike Liberia, the integration of private facilities into surveillance system in other countries was a challenge, compromising the completeness of reporting [13]. Despite the temporary interruption in reporting by the DSOs and ZSOs verified in 2017 in Liberia, the completeness of reporting remained high in 97%, since the private facilities continued reporting and ZSOs from Montserrado were supported by other partners. However, it affected negatively the number of supervisions conducted to the HCFs, being 50% (384/773) from September to November, 2017, far from the 80% recommended in IDSR guidelines. The consistent high completeness and timeliness of reporting was also contributed by the availability of resources like computer, printers and means of transport provided by WHO at district and county level. However, the same resources still not available at facility level in Liberia. The lack of resources, including reporting forms verified in Nairobi [22] and Nigeria [23] compromised the submission of weekly reports and other IDSR functions in general.

Although all the HCFs in Liberia had IDSR focal person, the follow up trainings were poor, representing only 46% (178/384) of IDSR focal point trained in the past year due to attrition of the previously trained staff. This may lead to poor quality of reporting, difficulties to use the standard case definition (relying more in clinical judgment), poor data analysis skills and inadequate supervisions and feedback to the community level as demonstrated in Tanzania in 2002 [24]. Liberia also had not integrated yet into IDSR other components of IHR (2005) like animal, food poisoning, chemical poisoning and disaster in the same level as other countries [17]. Instead, those events were classified as cluster of events and deaths. The qualitative questions from IDSR supervision revealed that the health workers were not satisfied with their level of training in IDSR, besides the workload, poor feedback with the issues raised in the supervision not addressed before the following supervision and inadequate means of transport and communication. The same findings were observed in qualitative study conducted in Zambia in 2016 [25]. Our study had several potential limitations. There was no information available about the implementation of IDSR in Liberia before the EVD outbreak. In addition, after the re-introduction of IDSR in 2015, different supervision tools were used, making difficult to compare the progress of indicators over the years. The assessment was also done by people from the county (DSOs) and information biases are expected. The interviews with the OICs were not recorded and transcribed, making impossible to reproduce verbatim quotes in our analysis. Despite these limitations, our findings can reliably be used for decision making and documentation.

Conclusion

Liberia has made remarkable progress in restoration of immunization service delivery following significant decline due to the devastating EVD outbreak in 2014-2015. There was improvement in immunization coverage for all antigens and reduced dropout rates at the national level. Key drivers for this can be associated with implementation of the immunization program within the GVAP framework and guidelines. However, there are still gaps within the system that need to be addressed in order to ensure maximum benefits from the immunization program. Some of these gaps include sub-optimal performance of immunization coverage and high drop-out rates at the county levels. Additionally, the quality of data for immunization service delivery is not optimal as there are discrepancies between administrative data and WUENIC data. The MCV coverage is still below elimination targets with sub-optimal population immunity and yet the country only has one dose of MCV in the immunization program. Nevertheless, Liberia has demonstrated strong capacity to adopt new technologies and vaccines into the immunization program with capacity to improve the health system and quality of service delivery. The primary strategies for successful introduction were country ownership, adaptation to country context and implementation within existing health system structures.

What is known about this topic

- Impact of the Ebola outbreak on routine immunization with decline in vaccination coverage and immunity levels in the 3 most affected countries (Liberia, Sierra Leone and Guinea);
- There were recurrent outbreaks of VPDs and increases vulnerability towards importation of wild polio virus;
- There was emphasis on rebuilding strong health systems in the affected countries to redress the impact of the outbreak and strengthen health system capacity to better handle similar adverse events in the future.

What this study adds

- Experience of Liberia on strengthening routine immunization following EVD outbreak control;
- Strategies and introduction of new technologies used to improve routine immunization in Liberia post Ebola outbreak;
- Existing gaps that needs improvement in Liberian context.

Competing interests

The authors declare no competing interest.

Authors' contributions

Authors conceived idea, with support from WHO scrutinized and identified the most appropriate literature. Authors analysed, synthesized and wrote the first draft of the manuscript. WHO provided further insights. The authors read and approved the final version of the manuscript.

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Research

Rapid response to meningococcal disease cluster in Foya district, Lofa County, Liberia January to February 2018

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Abstract

Introduction: early detection of disease outbreaks is paramount to averting associated morbidity and mortality. In January 2018, nine cases including four deaths associated with meningococcal disease were reported in three communities of Foya district, Lofa County, Liberia. Due to the porous borders between Lofa County and communities in neighboring Sierra Leone and Guinea, the possibility of epidemic spread of meningococcal disease could not be underestimated.

Methods: the county incidence management system (IMS) was activated that coordinated the response activities. Daily meetings were conducted to review response activities progress and challenges. The district rapid response team (DRRT) was the frontline responders. The case based investigation form; case line list and contacts list were used for data collection. A data base was established and analysed daily for action. Tablets Ciprofloxacin were given for chemoprophylaxis.

Results: sixty-seven percent (67%) of the cases were males and also 67% of the affected age range was 3 to 14 years and attending primary school. The attack rate was 7/1,000 population and case fatality rate was 44.4 % with majority of the deaths occurring within 24-48 hours of symptoms onset. Three of the cases tested positive for Neisseria Meningitidis sero-type W while six cases were Epi-linked. None of the cases had recent meningococcal vaccination and no health-worker infections were registered.

Conclusion: this cluster of cases of meningococcal disease during the meningitis season in a country that is not traditionally part of the meningitis belt emphasized the need for strengthening surveillance, preparedness and response capacity to meningitis.

Introduction

Meningococcal meningitis has been observed worldwide with the highest number of cases occurring in the meningitis belt of sub-Saharan Africa, that stretch from Senegal in the west to Ethiopia in the east (26 countries). For over 100 years, major epidemics of meningococcal disease have occurred every few years within the African meningitis belt with the most recent large-scale epidemic occurring in 2012 with over 22 000 cases and 1931 deaths [1]. The global burden of meningococcal disease has not been well documented due to inadequate surveillance system and documentation in some parts of the world. *Neisseria meningitides* serogroup A (Nm A) has been the cause of the majority of invasive meningococcal infections in the meningitis belt, although other strains such as serogroups C, X and W have also caused epidemics [1], and other pathogens such as *Haemophilus influenzae* type b (Hib) and *Streptococcus pneumoniae* (Spn) are also responsible for bacterial meningitis cases [1, 2]. Large meningococcal disease outbreaks caused by serogroup W have occurred in Burkina Faso in 2002 , recurred 10 years later; Burkina Faso in 2012, Niger (2010-2011), Chad (2009-10) and Guinea (2013). In all these outbreaks the proportion of infections among younger children (less than 10 years) was high [1, 3]. Liberia, a non-meningitis belt country shares border with Guinea and Ivory Coast which are in the meningitis belt. Meningococcal carriage, which represents the first step of disease transmission, varies with age and setting. It is known that *Neisseria meningitides* colonizes the nasopharynx in up to 5-10% of adults who are asymptomatic [4]. A recent study demonstrated that the carriage prevalence increases throughout childhood from 4.5% in infants to a peak of 23.7% in 19 year old subjects, then decreases to 7.8% in 50 year old adults [5]. The first time Liberia experienced a meningitis outbreak which was associated with attending a funeral in Sinoe County was in April 2017 where fourteen individuals with unknown illness including eight deaths were reported and *Neisseria meningitides* sero type C pathogen was the identified cause [6, 7]. *Neisseria meningitides* is transmitted from person-to-person through droplets of respiratory or throat secretions from carriers. Smoking, close and prolonged contact- such as kissing, sneezing or coughing on someone, mass gatherings or living in close quarters with a carrier-facilitates the spread of the disease .The bacteria can be carried in the throat and sometimes overwhelms the body´s defenses allowing the bacteria to spread through the bloodstream to the brain. It is believed that 1% to 10% of the population carries *Neisseria meningitides* in their throat at any given time. However, the carriage rate may be higher (10% to 25%) in epidemic situations [1, 3]. The average incubation period is two to four days, but can range between two and 10 days [3, 4, 8]. The most common symptoms are stiff neck, high fever, and sensitivity to light, confusion, headaches and vomiting. In addition in infants, excessive crying, bulging fontanels and limp body are commonly found. A less common but even more severe (often fatal) form of meningococcal disease is meningococcal septicemia, which is characterized by a hemorrhagic rash and rapid circulatory collapse [9, 10]. If untreated, meningococcal meningitis is fatal in 50% of cases and may result in brain damage, hearing loss or disability in 10% to 20% of survivors [4]. On January 13, 2018, Foya district health team (FDHT) notified the Lofa County Health Team (LCHT), the National Public Health Institute of Liberia (NPHIL) and the World Health Organization (WHO) of a cluster of unexplained health events that involved 9 cases including 4 deaths from three communities in Lofa County of Northern Liberia. These communities are located in a northern triangle consisting of Liberia bordering Sierra Leone and Guinea. On January 15, 2018, a team of National Public Health Institute of Liberia (NPHIL) and World Health Organization (WHO) epidemiologists were deployed from national level to support the county-led field investigation and response. Epidemiologic investigations performed included active case finding, determining the magnitude of the outbreak, and ascertaining the cause of unknown illness at that time. On January 22, 2018, *Neisseria meningitides* sero type W was confirmed by RT-PCR at National Reference Laboratory of Liberia (NRL) in specimens (oral swab, cardiac fluid and whole blood) collected from 3 cases. Cerebrospinal fluid (CSF) was not collected and tested due to lack of specimen collection materials and inadequate skills to perform lumbar puncture by health workers in the peripheral health facilities where the case patients were managed from. Ebola virus, Lassa fever, Yellow fever, Typhoid fever, Hepatitis A & C pathogens were ruled out. Response measures that included surveillance and active case search, contacts listing and follow up, appropriate clinical management of cases, chemoprophylaxis with ciprofloxacin, infection prevention and control, social mobilization and engagement with traditional healers, leaders of places of worship, local leaders; and dead body management were rapidly implemented to control the outbreak and prevent new cases and deaths. Meningitis surveillance in Liberia is implemented through the integrated disease surveillance and response system (IDSR), which captures priority diseases and conditions including unexplained clusters of health events and deaths [11, 12] reported from health facilities to the district, then up to the county and to the national level. This paper aims at describing the rapid response activities that were conducted to contain a cluster of meningococcal disease event in a remote part of the country within close proximity to both Ivory Coast and Guinea which are Meningitis belt countries.

Methods

Setting: Lofa County is one of 15 counties in Liberia with a total population of 358,613, located in northern region of the country, approximately 110 miles from the capital Monrovia and neighbouring countries of Guinea and Sierra Leone. Its many porous borders [13, 14] allowing free population movements, poor access to health services and inadequate safe water supply may increase the risk of outbreaks. In the last five years, the county has had outbreaks ranging from measles, Lassa fever, yellow fever, Ebola, acute bloody diarrhea (ABD) and cholera [13, 15].The inhabitants are predominantly farmers. The county has 59 health facilities (04 hospitals, 04 health centres and 51 primary clinics) with Telleweyan Memorial Hospital as the county referral hospital located in Voinjama city. Kelimabendu town the Epi- community is located at the triangle of the borders between Liberia, Guinea and Sierra Leone, and has an estimated population of 517 inhabitants. It is one of the catchment communities of the Mendikoma Clinic in Foya District, Lofa County. At Mendikoma Clinic, about 50% of the patients that seek care come from neighboring Sierra Leone and Guinea (Figure 1, Figure 2).

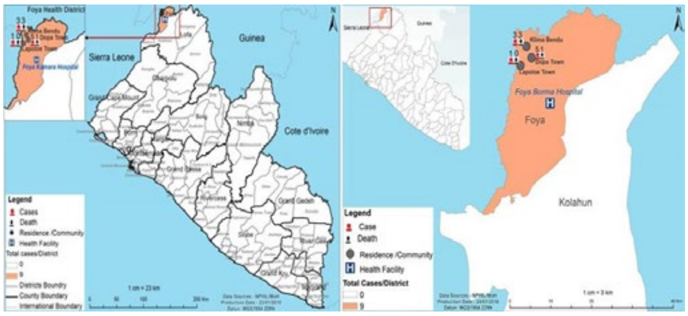

Figure 1: map of Liberia showing Lofa County on left and on the right Map of Foya district affected areas

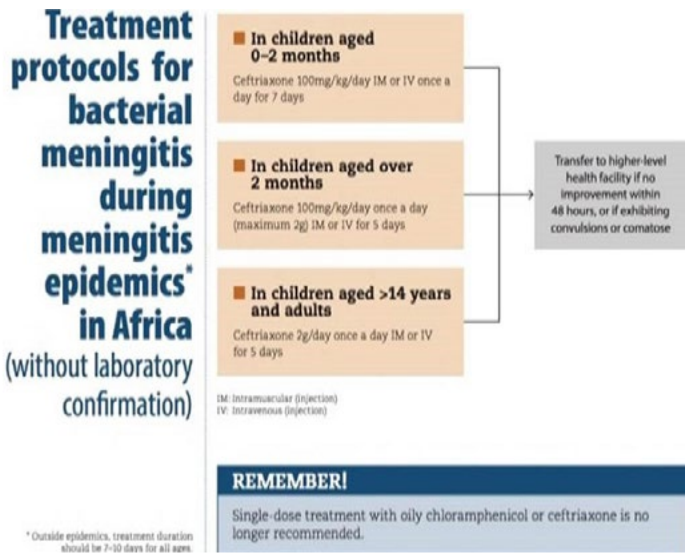

Figure 2: bacterial meningitis protocol

Case definitions: case definitions used included: 1) the initial case definition for **unexplained cluster of deaths:** two or more people in the same community who die suddenly of unknown or infectious cause after suffering similar symptoms as investigations were under way to establish the causes. 2) **Health facility case definition:** any person coming from or visiting Lofa County and presenting with two or more of the following symptoms: headache, vomiting, general body weakness, confusion, fever and among children, persistent crying, refusal to eat, fixed gaze, rigid body from December 23, 2017. 3) **Community case definition:** any person coming from or visiting Lofa County who is not feeling well from December 23, 2017.

Data collection: we used the data collection tools for outbreak response in Liberia, including the IDSR case based investigation form, line-list form, contact listing and daily follow-up form which were used to collect epidemiological, clinical, and demographic information on cases and their contacts [11]. District surveillance officers, district environmental health officers, district health officer, county surveillance officer conducted the case investigations and active case finding, with field supervision from WHO and national-level epidemiologists. The team interviewed patients and their relatives, community members, contacts, local leaders, traditional leaders and health facilities staff to understand circumstances and characteristics of the event.

Record review: data on clinical symptoms consistent with the case definition were reviewed for individuals seeking care during three months (October - December 2017) from outpatient department (OPD) registers, the IDSR ledger and inpatient case management charts and registers at all health facilities in Foya district. This was done to detect any cases that could have been unreported (Figure 3).

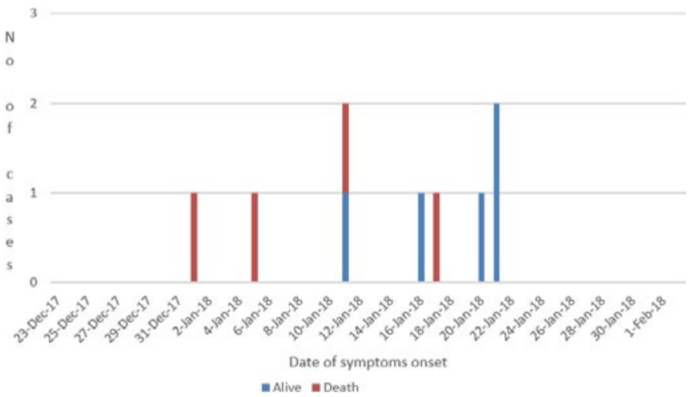

Figure 3: epicurve of menigococcal disease outreak, Foya District, Lofa County, 2017/2018

Case management: cases were managed at Foya Borma Hospital isolation unit. WHO managing meningitis epidemics in Africa; used for case management for this outbreak in Lofa County, Liberia [16].

Data analysis: all data were analyzed using Epi Info™ 7.0. Data from the IDSR case based investigation form, line-list form, patient medical records, contact listing and daily follow-up form which were used to collect epidemiological, clinical, and demographic information on cases and their contacts was analysed and the cluster event described for appropriate public health actions.

Results

Figure 4 shows the total cluster event cases since Jan 1, 2018 were 9 including 4 deaths (CFR: 44.4%). The index case died on 1st January 2018 however the cluster event was reported from the district to county and national level after death of the 3rd case that occurred 11th January 2018. The frequency of new cases based on the date of symptom onset peaked on January 21, 2018 with 3 new cases admitted on that day. 90% of the deaths occurred within 24-48 hrs of symptoms onset. Most cases and deaths were clustered around Kelimabendu the Epi-index community for the event. 90% of the cases were close family members from 03 households and attended the same place of worship. Most of the cases were students 06 (67%) from the same school which posed serious risk of spread among the pupils. There were no travel outside Liberia among cases and no significant associations observed with other potential exposures analyzed. The turn-around time for meningococcal disease laboratory results was on average 24 to 48 hours following the deployment of a vehicle for transportation of specimens from the field (Lofa County) to the national reference laboratory (NRL) in Margibi county, however the initial inability to suspect meningococcal disease among the index and second cases had an effect of delay in confirmation of the disease, initiation of appropriate treatment protocol and public health control measures. Nine (09) cases were line listed in one month period of which 6 (67%) were males. The median age affected was 12, range 3-85 years and 70% of the cases were aged 3-14years. Six (67%) cases were school going age children while 1(11%) was a pre-school child (Table 1).

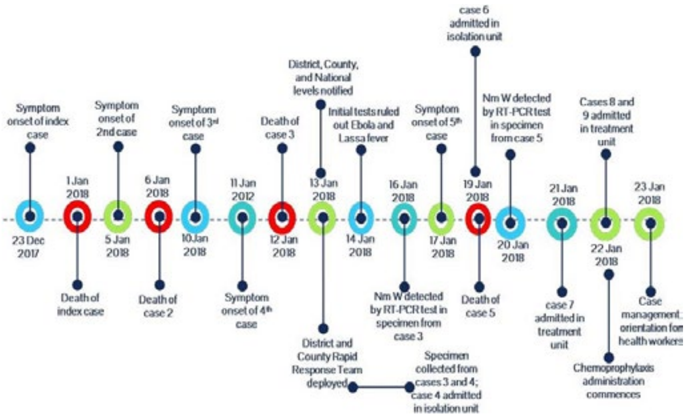

Figure 4: timeline of events of meningococcal disease outbreak, Foya District, Lofa County, Liberia, 23 December 2017 – 29 January 2018

Table 1: demographic data and geographical distribution of cases

Patient demographics			Occupation	Geographical distribution of affected communities in Foya district, Lofa county			Cases classification	
Initials of case	Sex (M:F)	Age (years)	Occupation	Kelimabendu-	Dopa	Laypalloe	Confirmed	Epi-Link
J N	M	45	Farmer and water pump mechanic	1(Died)				1
JJN	M	3	Not yet in school	1(Died)				1
TN	F	6	Primary school-student	1(Died)			1	
TJN	M	13	Primary school-student	1				1
J N	M	12	Primary school-student		1(Died)		1	
SK	M	85	Stays home (elderly)		1			
SC	F	12	Primary school-student		1			
MYN	F	8	Primary school-student			1	1	
JN	M	4	Kindergarten pupil		1			
Total	6M			4	4	1	3	6
	3F			9			9	

A total of 237 contacts ware followed daily for 10 days. As a result of active contact follow up, 4 cases were identified and early treatment initiated resulted in good prognosis. No health worker contacts developed symptoms (Table 2). Single dose oral ciprofloxacin 500 mg chemoprophylaxis was given to 233/237(99%) contacts, 103 non-contact health workers and 843 none contacts residents of affected communities; none of the contacts that took chemoprophylaxis developed symptoms of the meningococcal disease none of the contacts was pregnant or, a lactating mother. The attack rate was 7/1,000 population and the case fatality rate was 44.4% in January 2018 and the risk of getting meningococcal disease during January 2018 among the three ringed communities was very high in Dopa the last community to register cases (Table 3). Transmission involved 3 families in 3 closely linked communities (Figure 5).

One patient developed increased intracranial pressure, a complication of meningitis and was managed with Mannitol (0.25g/kg IV bolus over 5 min), furosemide (1 mg/kg IV bolus), dexamethasone to 10 mg IV qid, 30 % head elevation, urine output monitoring and nil by mouth (NBM),

Table 2: meningitis contact tracing, Foya District, Lofa County, 2018

Variables	TOTAL	Kelimabendu	Dopa	Laypalloe	Ndendu	Foya Town	Kolahun Town
Total contacts listed	237	82	72	45	6	25	7
Number (%) of contacts seen daily for 10days	237(100%)	82(100%)	72(100%)	45(100%)	6(100%)	25(100%)	7(100%)
% of contacts lost to follow up	0%	0%	0%	0%	0%	0%	0%
Not seen [number]	0	0	0	0	0	0	0
Total Health Care Worker Contacts	32	1	1	0	0	23	7
Number of cases identified through contacts follow up	4	0	3	1	0	0	0
Contacts completed 21 days (Graduated)	237(100%)	82(100%)	72(100%)	45(100%)	6(100%)	25(100%)	7(100%)
Number of Health care workers who became ill	0	0	0	0	0	0	0

Table 3: meningococcal disease attack rate per 1,000 populations in affected communities

Affected community	Community population	Number of cases	Attack rate per 1,000 population
Kelimabendu	517	4	8
Dopa	85	4	47
Laypalloe	689	1	1
Total	1291	9	7

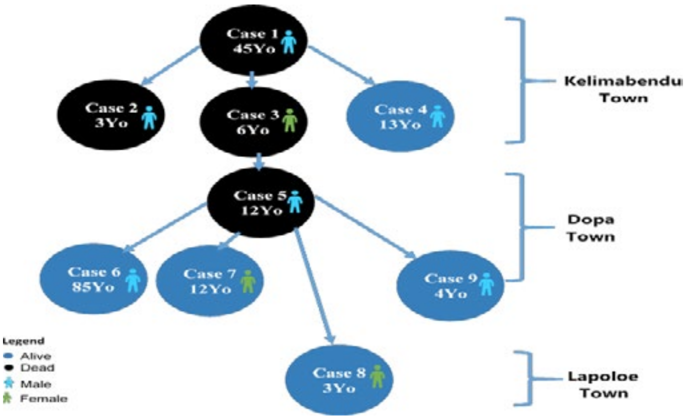

Figure 5: transmission chain

intravenous (i.v) maintenance fluids of 0.9% saline and 5% glucose to correct any potential hypoglycemia on addition to ceftriaxone. Oxygen was not available for supportive care and Lumbar puncture which is contraindicated in such cases was avoided. The index case 45 years old symptoms on set was on 23rd December 2017, however the case patient only sought care on 1st January 2018 and died the same day and subsequently three of his children became symptomatic and only one survived the illness. The last cases symptoms onset was 22nd January 2018; they were treated at Foya Borma hospital isolation unit and recovered. The meningococcal disease Lofa cluster ended after recording no new suspected or confirmed case and all line listed contacts finishing their ten days follow up.

Public health response: the Lofa County health team coordinated the investigation and response to the event with support from WHO and NPHIL. The County incidence management system (IMS) and Foya district RRT were activated and met daily to review field reports and progress of implementation of response activities. At the national level, the National Public Health Institute of Liberia (NPHIL) is providing technical and operational support to the county with support from WHO and US Center for Disease Control and Prevention. A total of 30 general community health volunteers (gCHVs) with supervision of district health officer, county surveillance officer and WHO epidemiologist conducted house to house active case search in the affected communities and ring health facilities to identify additional cases on addition to following up contacts two times a day for 10 days. A database was created to manage the epidemiological, clinical and laboratory data (Line list, contacts list and Laboratory results). Cross border engagement activities included 5 POE visited to as part of surveillance heightening process and information sharing with local health officials in neighboring communities in Sierra Leone and Guinea was regularly done. Infection prevention and control (IPC) measures were put in place (distribution of hand washing buckets, teaching sessions on respiratory hygiene and cough etiquette, avoiding close contact with sick people, and community engagement) as a means of breaking the chain of transmission. IPC standards and protocols were emphasized in affected communities, health facilities, public places and at points of entry. Use of risk appropriate personal protective equipment (PPE) by healthcare workers was reinforced, assessments for PPE availability in all health facilities in Foya district were conducted and all health facilities had adequate IPC supplies. Critically-ill patients were admitted to Foya Borma hospital isolation unit to reduce the likelihood of disease transmission. Persons with suspected or confirmed *Neisseria meningitides* infection were hospitalized at Foya Borma hospital isolation Unit. Immediate treatment with appropriate antibiotics (intravenous Ceftriaxone) according to case management protocol was initiated as after collection of blood specimens and this approach improved prognosis. One of the cases lost her sight as complication of the disease. Technical, medical supplies and logistics support were provided by WHO & NPHIL/ MOH.

In a bid to ensure adequate compliance to case management protocol and patient care, a total of 63 healthcare workers from Foya district were trained in the use of case management protocol for meningococcal disease while 38 health workers working at Foya Borma hospital (doctors, physician assistants and nurses) were oriented in management of complications of meningococcal disease. A total of 1,179 people (233 contacts, 103 non-contact health workers and 843 non contacts residents of affected communities) received single ciprofloxacin tablets as chemoprophylaxis as one of the quickest available prevention measures at the time. Meningococcal reactional vaccination was not carried out because the vaccine was not available in the country and the cluster size was considered small. Despite this idea; ministry of health remains focused to increase vaccination coverage against meningococcal disease in the country as the main prevention measure. Community engagement with local leaders, traditional healers, clan leaders and leaders of 17 places of worship (02 mosques and 17 churches) were critical in social mobilization and awareness to the public on addition to gCHV and community health development committee members that conducted house to house awareness. Information was also provided to the public through radio talk shows and street broadcasters, encouraging ill persons in the community to seek care at health facilities and encouraging community members on IPC practices. Two thousand five hundred (2,500) community members were sensitized on simplified case definition (syndromic) for meningococcal disease The index case and the second case were buried by the community while the subsequent cases that passed on were accorded safe and dignified burial by a trained district burial team supervised by the county environmental health officer. The community members who conducted the initial burials were placed on the contacts list received chemoprophylaxis and was under observation for 10 days. None of them developed signs and symptoms of the disease. The affected families and communities ware offered psychosocial support and counseling by a team of mental health clinicians in dealing with the emotional stress of the sudden death of their relatives and social stigma that developed. Health workers were also supported to emotionally respond to the event.

Discussion

The rapid response to the cluster of illnesses and deaths in Lofa County is a reflection of the increased public health and outbreak response capacity established in Liberia during and after Ebola epidemic and highlights the importance of enhanced surveillance systems [17], increased diagnostic capacity of the public health laboratory system and specimen referral; designated and trained rapid response teams, enhanced communications and information systems for outbreak response and the existence of a public health emergency operations center (EOC) as effective measures to prevent widespread disease outbreaks and other public health events [6, 18, 19]. In 2014, an initial cluster of illnesses and deaths resulting from EVD took more than 90 days from detection to coordination of the emergency response and led to a widespread Ebola epidemic [20]. In contrast, response efforts for this cluster of illnesses and deaths were initiated in less than 48 hours of detection by Lofa county health team, NPHIL, WHO and CDC. However, the CFR was very high (44%). Although the CFR is usually high in sub-Saharan Africa, reaching sometimes more than 60% [21], early diagnosis and treatment can reduce dramatically the number of deaths during meningococcal disease outbreaks [5, 22] to reach the level of the developed countries [23]. A study conducted in Niger in 2015 suggested that the CFR was 14.8% due to use of antimicrobial prophylaxis for the contacts like in Lofa County after the detection of the outbreak [24]. Meningococcal diseases typically include meningococcal meningitis and to some extent meningococcal bloodstream infection (septicemia). Patients with acute meningococcemia may present with meningitis, meningitis with meningococcemia, or meningococcemia without clinically apparent meningitis [25, 26]. A person can present with one or both features, as was the case with the cluster event in Lofa County unlike what was seen in Sinoe County southeast Liberia in May 2017 which was typically the septicemic type [6]. Clinicians worldwide need to be on the lookout for both types of manifestations in suspected meningitis cases. Meningococcal disease epidemics like any other outbreak are very disruptive, requiring the establishment of emergency treatment centers and placing a severe strain on the routine health services. The reason for the susceptibility of this region of Africa to major epidemics of meningococcal disease is in part related to its climatic features, with outbreaks occurring mainly in the hot, dry season [2]. During the dry season between December to June, dust winds, cold nights and upper respiratory tract infections combine to damage the nasopharyngeal mucosa, increasing the risk of meningococcal disease. At the same time, transmission of *Neisseria meningitides* may be facilitated by overcrowded housing [1, 2].

The fact that 67% of affected people were school age children posed a risk of spread among the school children due to overcrowding in the classroom and close contacts during playing at school. This event was similar to the case of Northern Nigeria and Niger in 2017 where the disease also mostly affected children between the ages of 5-14 years; making it more deadly since these age groups have lower immunity [27]. During these challenging periods, Liberia's Laboratory system demonstrated its preparedness to provide timely feedback for some basic tests post Ebola outbreak. The laboratory quickly ruled out Ebola, yellow fever and Lassa fever and confirmed *Neisseria meningitides* serotype "W" by RT-PCR. This helped to initiate appropriate effective case management and supportive treatment that increased survival among patients. For this cluster, cerebrospinal fluid (CSF) was not tested due to lack of specimen collection materials and inadequate skills to perform lumbar puncture by health workers in the peripheral health facilities. Lumbar puncture is recommended to be performed in all suspected cases with clinical signs and symptoms of invasive meningococcal disease (IMD) except in patients with prolonged seizures, immunocompromised patients, in the presence of signs of space-occupying lesions and in patients with severe impairment of consciousness and shock. In most cases; cerebrospinal fluid (CSF) reveals high opening pressure, pleocytosis, high protein levels and low glucose levels [28]. *Neisseria meningitides* should be detected in the CSF or blood by Gram staining, standard culture and/ or polymerase chain reaction (PCR) [27, 29, 30]. Some of the best practices noted during the response activities and appreciated during the post action review meeting include; timely situation report sharing with national level, partners, neighboring counties and countries (Sierra Leone & Guinea), administration of Chemoprophylaxis to contacts and non-contacts, massive awareness on local radio stations, market places and places, involvement of traditional, local and places of worship leaders in community engagement and social mobilization and distribution of simplified messages on signs & symptoms including preventive measures to mosques and churches as well as the timely provision of essential drugs by national public health institute of Liberia and WHO. During this cluster, it was noted that cases were not initially identified and reported early by community based surveillance due to lack of community health assistance in affected communities while at the primary health facilities cases were misdiagnosed due to inadequate knowledge on case definition of meningococcal disease, isolation facility was not fully prepared for the isolation and management of cases, limited infection prevention and control implementation at community level and inaquate laboratory capacity for basic general investigations like complete blood cell count and skills to collect appropriate specimens (e.g. Lumbar puncture for CSF) in rural health facilities affected the response.

Lessons learned: 1) prompt community engagement before, during, and after the outbreak and provision of regular feedback created high level of trust between the community and the response team; 2) recruitment of CHVs from their own community to conduct contact tracing enhance their cooperation and improve good surveillance practice; 3) administration of antibiotic prophylaxis and best IPC practices helped to prevent transmission of the disease; 4) the multi-sectorial collaboration resulted in the implementation of appropriate steps to prevent further transmission, and WHO determined the risk of recurrence of the meningococcal disease outbreak as low.

Recommendations: 1) the districts and county review and validate the epidemic preparedness and response plan (EPR) at the end of every outbreak; 2) the National Public Health Institute of Liberia (NPHIL) and ministry of health preposition IDSR sample collection materials including CSF collection kits to all hospitals in Liberia; 3) the County, MoH and partners re-activate the community based surveillance in areas where community health assistants (CHAs) are not assigned; 4) cross border surveillance activities should be prioritized by boarder counties and regular local information sharing among districts of neighboring countries encouraged; 5) clinicians worldwide need to be on look for both pictures in suspected meningitis cases, the IDSR and meningitis clinical management literature may require updating to future this possibility; 6) as part of preparedness the need to prioritize meningococcal vaccination to populations at high risk and health workers is key despite its cost implication; 7) the occurrence of a second health event of meningococcal disease in anon meningitis belt country during the meningitis outbreak season suggests the inclusion of Liberia in the belt.

Conclusion

The successful response to this cluster demonstrates the increased capacity of Liberia's public health system to rapidly detect and effectively respond to public health threats and enhance global health security. The need to prioritize stocks of meningitis vaccines, laboratory supplies and ensuring epidemiologic surveillance and response systems are to public health events is in place through CRRTs and DRRTs in Liberia are established, are key health capacities Liberia is contributing to global health security. Implications of this documentation: clinicians worldwide need to be on lookout for both features in suspected meningitis cases, the IDSR and meningitis clinical management literature may require updating on this possibility while the occurrence of a second health event of Meningococcal disease in a non- meningitis belt country during the meningitis outbreak season suggests the inclusion of Liberia in the belt. As part of preparedness the need to prioritize meningococcal vaccination to populations at high risk and health workers is key despite its cost implication.

What is known about this topic

- Infection with Neisseria Meningitidis easily progress to Meningococcal Sepsis, also known as Meningococcemia, causing a rash, hemorrhage, and multi-organ failure as was the case in the Sinoe county-Liberia situation;
- Neisseria Meningitidis serotype C was identified.

What this study adds

- Documentary evidence for the infection progression with both Meningitidis and Meningococcemia features occurring together as was the case in this event;
- Neisseria Meningitidis serotype W was identified by RT-PCR for the first time in Liberia.

Competing interests

The authors declare no competing interest.

Authors' contributions

Julius Monday Rude and Lavele Kortimai: study design, data collection, data analysis, manuscript writing and submission. Julius Monday Rude compiled final version of the manuscript incorporating all authors' inputs. Fallah Mosoka, Baller April, Williams Desmound, Mouhamoud Nuha, Victoria Katawera, Alpha Tamba, Emmanuel Musa Onuche and Thomas Nagbe: data collection, data analysis and read critically the manuscript, provided the necessary corrections and approved for submission. Alex Gasasira, Tolbert Nyenswah, Ibrahima Socé Fall, Soatiana Rajatonirina and Bernice Dahn read critically the manuscript and provided corrections, inputs and were involved in data collection and data analysis. Joseph

Okeibunor Chukwudi, Ambrose Talisuna, Formenty Pierre, Alex Gasasira, Ahmed Ali Yahaya: data collection, data analysis, read critically reviewed, corrected and approved the manuscript. Authors conceived idea, scrutinized and identified the most appropriate literature. Authors analysed, synthesized and wrote the first draft of the manuscript. WHO provided further insights. The authors read and approved the final version of the manuscript.

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Research

Lessons learned from detecting and responding to recurrent measles outbreak in Liberia post Ebola-Epidemic 2016-2017

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Abstract

Introduction: measles is an acute viral disease that remains endemic in much of sub-Sahara Africa, including Liberia. The 2014 Ebola epidemic disrupted an already fragile health system contributing to low uptake of immunization services, population immunity remained low thus facilitating recurrent outbreaks of measles in Liberia. We describe lessons learnt from detecting and responding to recurrent outbreaks of measles two years post the 2014 Ebola epidemic in Liberia.

Methods: we conducted a descriptive study using the findings from Integrated Diseases Surveillance and Response (IDSR) 15 counties, National Public Health Institute of Liberia (NPHIL), National Public Health Reference Laboratory (NPHRL) and District Health Information Software (DIHS2) data conducted from October to December, 2017. We perused the outbreaks line lists and other key documents submitted by the counties to the national level from January 2016 to December 2017.

Results: from January 2016 to December 2017, 2,954 suspected cases of measles were reported through IDSR. Four hundred sixty-seven (467) were laboratory confirmed (IgM-positive), 776 epidemiologically linked, 574 clinically confirmed, and 1,137 discarded (IgM-negative). Nine deaths out of 1817 cases were reported, a case fatality rate of 0.5%; 49% were children below the age of 5 years. Twenty-two percent (405/1817) of the confirmed cases were vaccinated while the vaccination status of 55% (994/1817) was unknown.

Conclusion: revitalization of IDSR contributed to increased detection and reporting of suspected cases of measles thus facilitating early identification and response to outbreaks. Priority needs to be given to increasing the uptake of routine immunization services, introducing a second dose of measles vaccine in the routine immunization program and conducting a high-quality supplementary measles immunization campaign for age group 1 to 10 years to provide protection for a huge cohort of susceptible.

Introduction

Measles is an acute viral infectious disease caused by a virus in the paramyxovirus family and an important cause of childhood morbidity and mortality [1]. In 2015, there were 206,360 cases of measles reported globally with 42,083 reported in the African region [2]. Measles is part of the list of 14 epidemic prone diseases for weekly reporting under IDSR in Liberia [3]. In September 1998, the World Health Organization-Regional Committee for Africa (WHO/AFRO) adopted the Integrated Disease Surveillance and Response (IDSR) strategy for priority diseases, conditions and events as one of the key aspects of disease control in the WHO African Region that leads to early detection, appropriate investigation, laboratory confirmation and timely response to public health conditions and events [4-6]. The Liberia Ministry of Health (MOH) adapted the second edition of the generic integrated disease surveillance and response technical guideline in 2014 supported by World Health Organization-Regional Office for Africa (AFRO) in collaboration with the United States Centers for Disease Control and Prevention (CDC) in Atlanta. The guidelines aimed at contributing to reduction of mortality, morbidity and disability from diseases, public health events and conditions through timely, accurate, complete reporting and analysis of data for public health action. The guidelines serve as a general reference for surveillance activities across all levels of the health system [4] and were revised in 2016 to suit the prevailing national situation. As a lesson learnt from EVD outbreak in Liberia [7], the strengthened IDSR has led to increased reporting of suspected cases, laboratory confirmation as well as linkage of epidemiological and laboratory data for detection and response to measles outbreaks throughout the country. This paper aims at highlighting the lessons learned from enhanced surveillance and response to measles through IDSR. These lessons and recommendations will contribute to the quality of measles surveillance and response as well as the global measles elimination efforts.

Methods

Study setting: Liberia has 15 political divisions or counties which are further subdivided into 91 health districts. The projected estimated population of Liberia in 2017 according to Liberia's Health Management Information System (HMIS) was 4,514,112. In 2017, there were a total of 761 health facilities, all of which submitted weekly surveillance reports on 14 nationally identified immediately reportable diseases, conditions and events through the IDSR strategy. There is also a National Public Health Reference Laboratory (NPHRL) responsible for the confirmation of suspected cases requiring testing. The NPHRL currently has testing capacity for eight priority diseases (measles, Ebola, yellow fever, lassa fever, Rubella, Shigellosis, cholera and meningitis).

Study design: we conducted a descriptive and cross-sectional study to analyze the data from all the measles outbreaks reported from January 2016 to December 2017 and immunization data from 2012 to 2017.

Standard case definition: we adopted the standard case definitions from the National Technical Guidelines for IDSR and WHO's recommended standards for surveillance of selected vaccine-preventable diseases: **suspected case:** any person with fever and generalized maculo-papular (non-vesicular) rash plus one of the following: Cough coryza or conjunctivitis (red eyes); or any person in whom a clinician suspects measles. **Confirmed case:** a suspected case with laboratory confirmation (positive IgM antibody) or epidemiological link to confirmed cases in an outbreak. **Epidemiologically confirmed case:** any case that meets the suspect case definition and is linked to a laboratory confirmed case. **Clinically confirmed case:** a case that meets the suspect case definition and a clinician is convinced to be measles in absence of laboratory confirmation [3].

Thresholds: an IDSR alert threshold was defined as one suspected measles case reported by a district in a week. The epidemic threshold was defined as five or more suspected cases or three confirmed cases reported from a district in one month [8].

Response to measles outbreaks: the IDSR alert and epidemic thresholds along with spatial and temporal clustering of cases were used to detect outbreaks. For each outbreak detected, a response from the district rapid response team (DRRT) was mounted within 48 hours after the confirmation of the outbreak and in some cases supplemented by the county response team with in 72 hours. Response to measles outbreaks included active case search in communities and line listing of all cases, record review at health facility to identify missed cases, and symptomatic management of cases including administration of high dose of vitamin A. Reactive vaccination campaigns were conducted in selected communities in some districts with variation among targeted age group for each campaign depending on the population most affected and most vulnerable. Engagement of communities using local health volunteers to report suspected cases, seek care and utilize existing immunization services became a mainstay of the response strategy to outbreaks.

Data collection: we obtained weekly measles IDSR surveillance data reported by the county surveillance officers covering each of the 15 political divisions of the country. These reports were also complemented by weekly laboratory results released by the National Public Health Reference Laboratory. When a health district crossed the epidemic threshold and reported outbreaks, the measles outbreak reports and line list were obtained and used as a data source.

Immunization: immunization records were obtained from the Health Management Information System (HMIS). We reviewed immunization records from 2012 to 2017 across the country. Records of reactive immunization during outbreaks were also obtained.

Data analysis: univariate and multivariate analysis were performed using Microsoft™ Excel 2013 and Epi Info™ 7.0. We analyzed the data to describe demographic and epidemiological characteristics such as attack rate, age group, sex, and vaccination status. Patients confirmed cases were divided into 4 age groups: < 1 year, 1-4 year, 5-9 year, ≥ 10 year. We performed F-test to compare the distribution of cases by age range, gender and vaccination status, and student-t test to compare the variation of cases from 2016 to 2017. Positive predictive value which was defined as the proportion of measles case-patients who had a positive measles serological result (IgM +) [9] was also calculated for each county and presented in tables. Arc GIS was used to provide spatial analysis and presentation of the data on maps. Following discussions with ministry of health ethics committee and National Public Health Institute of Liberia for which permission to proceed with the research and data analysis was granted the IRB review request was not considered.

Results

Epidemiological description of the measles outbreaks: a total of 2,954 suspected cases of measles were reported from all 15 counties. Using WHO classification scheme for measles [6], 467 were laboratory confirmed (IgM-positive), 776 epidemiologically confirmed, 574 clinically confirmed, and 1,137 discarded (IgM-negative) (Figure 1, Figure 2, Figure 3, Figure 4, Figure 5). The ratio of males to females was not statistically significant among confirmed cases ($p = 0.25$). The median age among confirmed cases was 5 years with an inter-quartile range of 1-8. Among the confirmed cases, the most affected age group was 1-4 year with 37% of cases (667/1817) ($p < 0.001$). Vaccination status among confirmed cases were as follow: vaccinated-405 (22%) ($p < 0.001$), not-vaccinated-418 (23%) ($p < 0.001$), and unknown-994 (55%) ($p = 0.85$) (Table 1). Nine deaths were reported among confirmed cases in both reporting years with a case fatality rate of 0.5% (9/1817), six of them not vaccinated and three with unknown vaccination status. Thirteen health districts in six counties reported outbreaks in 2016 and in 2017. In 2017, 29 outbreaks were recorded involving 955 confirmed measles cases. Case fatality rate among confirmed cases was 0.42% (4/955). Most outbreaks 83% (24/29) were responded to within 48 hours of detection (Table 2). Although the counties with outbreaks in 2016 and 2017 were the same, there was variation in the number of cases and distribution among the health districts with outbreaks between the two years (Figure 6), with more districts involved and cases reported in 2017 compared to 2016. From 2016 to 2017, the number of confirmed cases increased in all the counties, except Grand Bassa, Grand Gedeh, Lofa and Margibi. There was an overall not significant increase in number of cases from 2016 to 2017 ($p = 0.39$) in the entire country.

Laboratory description: blood specimens for measles testing were obtained from a total of 1,669 suspected cases (451 in 2016 and 1,218 in 2017) and sent to the National Public Health Reference Laboratory. Excluding epi-linked cases, the proportion of suspected cases with blood specimens collected increased from 70% in 2016 to 80% in 2017. The total number of measles specific IgM positive samples increased from 150 in 2016 to 317 in 2017. The positive predictive value among samples tested decreased from 33% in 2016 to 26% in 2017 (Table 3).

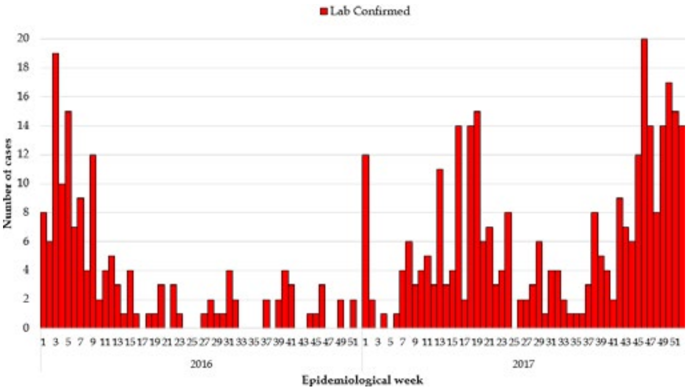

Figure 1: laboratory confirmed measles cases 2016 and 2017

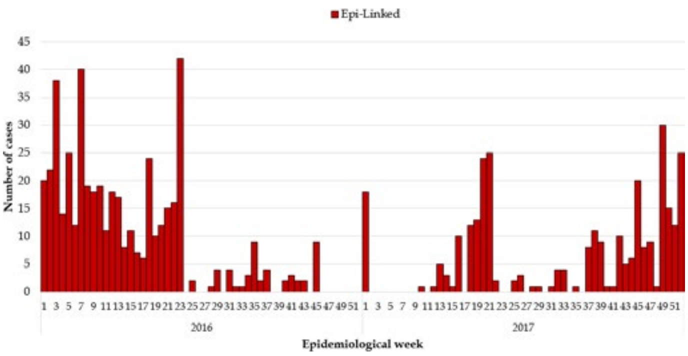

Figure 2: measles Epi-Linked cases 2016 and 2017

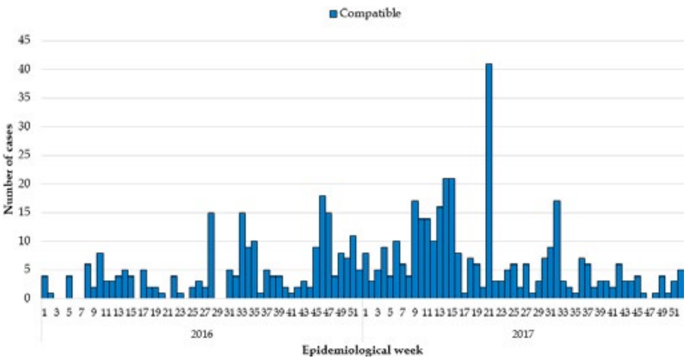

Figure 3: clinically compatible measles cases 2016 and 2017

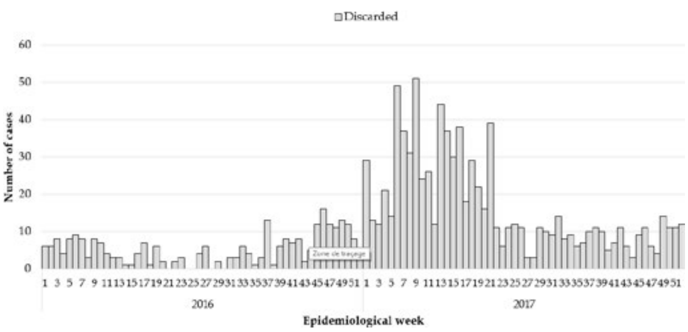

Figure 4: discarded measles cases 2016 and 2017

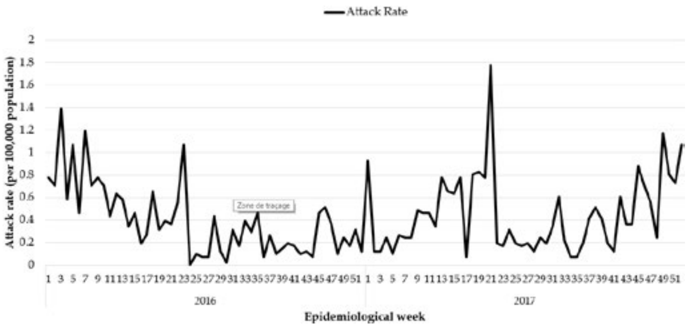

Figure 5: measles attack rate in Liberia 2016 and 2017

Table 1: outbreak log of measles, Liberia, 2016 – 2017

				Sex		Age	Vaccination Status					
	County	Date Reported (Date/Month/Year)	Districts affected	Male (%)	Female (%)	Median Age	Vaccinated (%)	Not Vaccinated (%)	Unknown (%)	No. of deaths	CFR (%)	Duration from Notification to Response (days)
1	Bomi	9/1/2016	Senjeh, Klay	19 (54%)	16 (46%)	6	11 (31%)	3 (9%)	21 (60%)	0	0	2
2	Bong	17/6/2016; 11/5/2017; 14/9/2017; 15/11/2017	Zota, Suakoko	70 (47%)	78 (53%)	5	11 (7%)	39 (26%)	98 (66%)	0	0	1
3	Gbarpolu	3/1/2017	Bokomu	8 (53%)	7 (47%)	6	8 (53%)	0 (0%)	7 (47%)	0	0	2
4	Grand Bassa	10/1/ 2016; 10/5/ 2016; 4/3/2017; 4/3/2017; 12/6/2017	Buchanan, Wood camp, District number 3 and 4	114 (53%)	103 (47%)	5	9 (4%)	112 (52%)	96 (44%)	2	0.92	9
5	GCM	14/1/2017	Tewor	4 (67%)	2 (33%)	6	1 (17%)	0 (0%)	5 (83%)	0	0	
6	Grand Gedeh	11/1/2017	Tchien, Konobo	20 (51%)	19 (49%)	5	6 (15%)	5 (13%)	28 (72%)	0	0	
7	Grand Kru	16/2/2017	Buah	1 (33%)	2 (67%)	6	0 (0%)	1 (33%)	2 (67%)	0	0	
8	Lofa	16/1/2016; 31/3/2017;	Voinjama,Zorzor, Foya	103 (50%)	102 (50%)	5	71 (35%)	20 (10%)	114 (56%)	0	0	2
9	Margibi	5/1/2016, 3/10/2016; 8/5/2017	Gibi,Kakata, Firestone	130 (48%)	143 (52%)	5	37 (14%)	96 (35%)	140 (51%)	2	0.73	8
10	Maryland	3/3/2017	Pleebo	26 (55%)	21 (45%)	6	2 (4%)	0 (0%)	45 (96%)	0	0	2
12	Montserrado	5/1/2016; 18/2/2017; 6/3/2017; 25/10/2017; 1/11/2017; 24/11/2017; 1/12/2017;	Bushrod,St Paul, Common wealth, Somalia drive	255 (50%)	251 (50%)	5	195 (39%)	99 (20%)	212 (42%)	1	0.2	7
12	Nimba	17/2/2016; 24/4/2017; 21/7/2017; 11/8/2017; 4/11/2017; 15/10/2017	Tappita, Saniqueille Mah,Yarwin, Mensonnoh	145 (49%)	153 (51%)	5	52 (17%)	42 (14%)	204 (68%)	4	1.34	7
13	River Gee	13/3/2017	Webbo	3 (60%)	2 (40%)	6	2 (40%)	0 (0%)	3 (60%)	0	0	2
14	Rivercess	4/4/2017	Morweh	3 (27%)	8 (73%)	5	0 (0%)	0 (0%)	11 (100%)	0	0	2
15	Sinoe	19/5/2017	Greenville	4 (44%)	5 (56%)	6	0 (0%)	1 (11%)	8 (89%)	0	0	2
	Grand Total			904 (50%)	911 (50%)	5	405 (22%)	418 (23%)	994 (55%)	9	0.49	
												≤ 48 hours
												3 - 7 days
												>7 days

Table 2: measles surveillance by county, Liberia, January 2016-December 2017

County	2016				2017			
	Total cases requiring sample collection	Total samples collected	% of samples collected	Ig M positve	Total cases requiring sample collection	Total samples collected	% of samples collected	Ig M positve
Bomi	29	26	90%	3	93	69	74%	1
Bong	34	31	91%	11	91	86	95%	27
Gbarpolu	10	5	50%	0	19	15	79%	3
Grand Bassa	47	45	96%	24	82	54	66%	19
Grand Cape Mount	5	4	80%	0	37	36	97%	3
Grand Gedeh	30	10	33%	0	74	62	84%	4
Grand Kru	3	3	100%	0	23	21	91%	1
Lofa	131	50	38%	4	196	134	68%	8
Margibi	132	114	86%	56	153	141	92%	15
Mary Land	5	5	100%	0	98	52	53%	1
Montserrado	196	132	67%	49	375	293	78%	148
Nimba	17	12	71%	3	192	172	90%	83
River Gee	2	2	10%	0	13	10	77%	1
River Cess	3	3	10%	0	39	33	85%	3
Sinoe	7	6	86%	0	45	40	89%	0
Grand Total	**648**	**451**	**70%**	**150**	**1530**	**1218**	**80%**	**317**

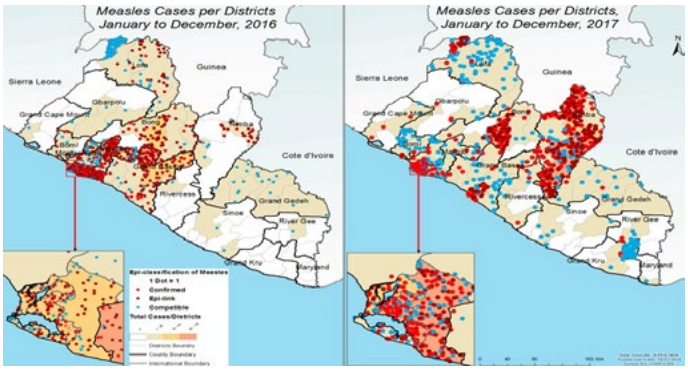

Figure 6: comparison of geographical distribution of confirmed cases of measles in Liberia, 2016 and 2017

Measles immunization coverage: records from the HMIS showed that routine measles vaccination (MCV1) coverage declined from 74% in 2013 to 61% and 64% in 2014 and 2015 respectively before picking up at 80% in 2016 and 87% as of December 2017. Analysis of measles coverage by county shows variation in performance. The proportion of districts attaining routine measles vaccination coverage above 80% decrease from 4 (4.4%) in 2013 to 1 (1.1%) in 2014 and increased to three (3.3%) in 2015, 6 (6.7%) in 2016 and 9 (10%) in 2017. The proportion of districts reporting less than 50% measles vaccination coverage increase from 0 in 2013 to 3 in 2014 and then declined to 2, 1, and 0 in 2015, 2016, and 2017 respectively (Table 4). Due to recurrent measles outbreaks, 15 reactive vaccinations campaigns were conducted in five counties, targeting 63 affected and surrounding communities in 2016 and 18 communities in 2017. Seven counties out of the total 15 counties 7/15 (46.7%) did not reach the national measles coverage target of 80% in 2017. The situation was worse in 2013 where only 4/15 (27%) counties achieved this target.

Table 3: administrative coverage of measles-containing vaccine from 2013 to 2017 and reactive campaign vaccination coverage from 2016 to 2017

	MCV1 administrative Coverage (%)					Reactive local vaccination				
County	2013	2014	2015	2016	2017	No. of districts with campaign	No. of communities (2016)	No. of communities (2017)	Coverage (%) 2016	Coverage (%) 2017
Bomi	87%	70%	72%	93%	92.6%	-	-	-	-	-
Bong	92%	83%	108%	111%	113.3%	2	14	3	81%	113%
Gbarpolu	71%	58%	56%	92%	89.4%	-	-	-	-	-
Grand Bassa	64%	60%	75%	79%	82.2%					
Grand Cape Mount	82%	46%	58%	64%	62.0%	-	-	-	-	-
Grand Gedeh	71%	60%	51%	61%	65.6%	-	-	-	-	-
Grand Kru	80%	77%	58%	96%	106.6%	-	-	-	-	-
Lofa	70%	60%	63%	93%	91.5%	1	10	-	89%	-
Margibi	63%	55%	63%	98%	77.8%	3	37	1	78%	85%
Maryland	58%	57%	45%	65%	61.5%	-				
Montserrado	72%	47%	55%	74%	86.2%	0	0	0	0	0
Nimba	73%	58%	55%	73%	98.3%	4	2	14	31%	78%
River Gee	69%	40%	31%	42%	62.2%	-	-	-	-	-
Rivercess	75%	75%	82%	79%	74.9%	-	-	-	-	-
Sinoe	69%	73%	81%	77%	78.0%	-	-	-	-	-
Liberia	74%	61%	64%	80%	87.1%					
% of district with MCV1 ≥80%	4	1	3	6	9	-	-	-	-	-
% of district with MCV1 <50%	0	3	2	1	0	-	-	-	-	-

Table 4: reactive measles vaccinations during measles outbreaks, Liberia, 2016 – 2017

Year	Dates	County	Health District	Number of cases	Age group targeted	Number targeted	Number Vaccinated	Coverage (%)
2016	4-11 March	Bong	Suokoko	6	6-59 months	340	223	66
2016	7-11 March	Nimba	Zoe Geh	8	6-59 months	4257	1010	24
2016	14-18 March	Margibi	Mamba Kaba, Fire stone & Kakata	112	9-23 months	9916	7152	72
2016	22-23 March	Bong	Sanoyea	4	6-59 months	1128	973	86
2016	12-16 September	Lofa	Foya	30	6-59 months	12938	11540	86
2016	19-23 September	Nimba	Saclepea Mah	434	6-59 months	351	434	124
2016	3-7 October	Margibi	Firestone	4	9-11 months	2620	2620	100
2017	1-5 May	Nimba	Tappita	79	6-59 months	1290	1746	135
2017	8- 12 May	Margibi	Gibi	5	9-11 months	420	355	85
2017	14-18 August	Nimba	Zoe Geh	10	6-59 months	194	111	57
2017	18-28 September	Bong	Suokoko	4	6 months - 10 years	1002	839	84
2017	16-30 October	Bong	Suokoko	3	7 months - 10 years	1491	1969	123
2017	23-27 October	Nimba	Zoe Geh	11	6-59 months	400	300	75
2017	6-24 November	Bong	Zota	3	7 months - 10 years	1015	839	83
2017	11-15 December	Nimba	Sanniquellie	46	6-59 months	1816	715	39

Discussion

Since the revitalization of IDSR in Liberia towards the end of 2015, detection, reporting, and response to outbreaks of measles in the following two years has improved. The total number of suspected measles cases reported in Liberia increased from 1,134 cases in 2016 to 1,820 cases in 2017. The improved detection and reporting of cases may be attributed to training of health workers across the country in IDSR, mentorship of frontline health workers on measles case definition and treatment as well as the introduction of community events based surveillance system where measles is one of the 14 triggers (using pictorial and simplified definitions) notifiable by community health workers to the nearest health facility. The age group 1-4 years old was the most affected constituting 37% of the confirmed cases followed by 5-9 years age group constituting 29% of the cases. Although, the national Expanded Program on Immunization (EPI) offers a single dose of measles-containing vaccine to children at age 9 months [10], the most affected age group were above those covered in routine immunization. The huge burden of cases above the target age for routine vaccination can be explained in terms of the number of missed children who have formed part of a large susceptible population. Additionally, failure to seroconvert may account for cases among those previously vaccinated despites having received a dose of the vaccine. According to a study conducted by Işik et al., among 115 children seroconversion rate was 77.6% after the first dose at 9 months of age and 81.9% after the second dose of measles vaccine at 15 months [11]. Studies indicate that more than 99% of persons who receive two doses of measles vaccine (with the first dose administered no earlier than the first birthday) develop serologic evidence of measles immunity [12]. However even when vaccination coverage is high measles outbreaks may still occur if the quality of the vaccination program (vaccine potency, route of administration, and dosage policy) does not offer enough protection among the population.

Laboratory confirmation: measles diagnosis is confirmed by Laboratory and in Liberia only the National Reference Laboratory (NRL) offer testing for measles in the country. Whenever measles is suspected, whole from the first 5-10 suspected measles cases is sent to the NRL for confirmation. When 3 measles cases are confirmed from the same district within a period of 30 days, a measles outbreak is declared and additional measles cases reported are epidemiologically liked and line listed [13]. In 2016, the national percentage of 70% fell below the WHO target of 80% for minimum proportion of suspected cases requiring samples collection [14], however, the target of 80% was achieved in 2017 highlighting improvement in surveillance and laboratory. Sensitivity of the surveillance system also increases with high number of suspected cases reported in 2017 compared to 2016. Positive predictive value in both years remains above the WHO AFRO Regional target of 10%, suggesting the endemicity of measles in the country. Virus detection, sequence information and oropharyngeal swab specimens are not currently in Liberia. This sequence information can be of much value to the national control programs, determine transmission pathways, and define geographical distribution of measles virus genotypes.

Clinical management of measles cases: the WHO recommendations for administration of vitamin A and supportive care to patients diagnosed of measles was used which is attributed to high recovery rate, low case fatality rate and post measles complications [15]. The supportive treatment provided for all measles cases at secondary and tertiary health facilities include the administration of additional fluids (such as oral rehydration solution) and antipyretics. Antibiotics were used for measles complicated by otitis media, pneumonia or other suspected sepsis and nutritional therapy given to children with malnutrition. All patients suffering from measles were screened for malnutrition and those found malnourished were referred to the nutrition rehabilitation units of county referral hospitals for appropriate care using the WHO protocol on Integrated Management of Childhood Illnesses (IMCI) [16].

Immunization: routine immunization coverage has been improving in the aftermath of the Ebola virus disease outbreak. In 2014, routine immunization coverage dropped to the lowest in a decade due to the EVD outbreak which disrupted the provision of routine health services across the country. However, in 2016 and 2017 the country was able to achieve the target of 80% or above measles immunization administrative coverage. Despite the national average at 80% and 87% in 2016 and 2017 respectively, Montserrado and Nimba counties, the most two populous counties fell below the 80% mark. Additional analysis of counties that achieved the 80% at district level, 10% of the 92 health districts had not achieved 80% coverage or above in the last 5 years. Circumscribed reactive measles immunization campaigns were conducted in the districts with outbreaks coordinated by the district and county rapid response teams (CRRT) and (DRRT) as a response measure to measles outbreaks on addition to intensification of routine immunization in affected counties, however vaccine hesitancy continues to affect the coverage especially in the Mandingo and Fula tribes' communities. The local epidemiology of the disease informed the target age group for each reactive measles campaign.

Social mobilization and community engagement: during measles outbreaks in Liberia, community engagement and awareness activities are intensified in affected communities aimed at encouraging the population to utilize routine vaccination services, reactive measles campaigns reporting all suspected cases of measles to health facilities early. Traditional healers are also engaged to refer all suspected measles patients to the nearest health facilities. Community health workers, volunteers, leaders of places of worship, markets leaders and women groups were used for risk communication guided by ministry of health and county health promotion units. Messages to the community were brief, concise and translated in local dialects which were transmitted through local radios, jingles, posters and fliers. The messages provided information about the disease with focus on signs and symptoms, prevention through measles vaccination and encouragement to seek care at the nearby health-care facility early after symptom onset. Community engagement meetings were held with community, religious and political leaders, and presentations at markets, health centers, town hall meetings, schools and places of worship.

Lessons learnt: a key lesson in this context is the fact that low immunization coverage is a recipe for outbreaks. The use of community informants for detection and reporting priority diseases of which measles is among increase measles alerts reporting hence contributing to early measles outbreak detection. Community engagement is a critical part of response and control efforts. Involvement of communities through their chiefs, elders, women and youth groups builds trust and facilitates cooperation from community members during response activities.

Limitations: few children had vaccination cards to verify routine vaccination history. However, even among children with cards, measles coverage remained low (78%) for all counties combined (data not shown). Majority of the measles cases reported (55%) vaccination status was unknown; this posed a challenge in data analysis and interpretation of study findings. It was difficult to establish whether the large number of cases with unknown vaccination was non-vaccinated or vaccinated due to missing records, incomplete data and recall challenge from the caretakers. It can also be partly attributed to the poor quality of information asked for recall of vaccination status by health workers. Information about reactive campaigns following measles outbreak was only available in 4 out of 10 counties (40%).

Recommendations: given that measles incidence is particularly very high among age group 1 to 10 years, which constitute 65% of all confirmed cases, need to conduct a national campaign targeting 6 months to 15 years. Liberia still offers one dose of measles vaccine in the routine immunization schedule. There is need to introduce the second dose measles vaccine in the routine immunization schedule of the country. Strengthening of surveillance and epidemic preparedness and response with emphasis on ensuring emergency resources are readily available at sub-national level for quick response need to be prioritized. Strengthen community engagement to ensure a higher uptake of immunization services.

Conclusion

Revitalization of IDSR as a lesson learnt from Ebola outbreak has provided immense opportunity for improving case detection and response to measles. The introduction of booster doses as part of routine immunization need to be considered. Supplemental immunization campaign and strengthening of routine immunization core activities need prioritization as a hall mark to reduce the persistence of measles and prevent out breaks in Liberia, West Africa and AFRO region.

Availability of data and materials: the identified data used and/or analysed during this documentation is available from the corresponding authors and a property of Liberia ministry of health.

What is known about this topic

- Measles is a highly contagious respiratory disease;
- Measles typically starts with fever, runny nose, cough, red eyes and sore throat followed by Koplik spots, or tiny white spots developing inside the mouth and a rash that starts on the face spreading downward to the rest of the body;
- Measles can be prevented with the MMR (measles, mumps, rubella) vaccine, which is safe and effective.

What this study adds

- Accumulation of a large susceptible population with an immunity gap is a risk for large scale measles outbreaks as seen in Liberia where 51% of measles cases were above 5 years;
- Circumscribed reactional measles vaccination is good at interrupting transmission of measles during outbreaks hence reducing morbidity due to measles;
- Measles vaccination in life time is protection for measles infection.

Competing interests

The authors declare no competing interest.

Authors' contributions

Thomas Nagbe, George Sie Williams and Sumor Flomo led the development of the manuscript, outbreaks investigation, collected data, analysis, interpretation, drafted and coordinated manuscript writing and wrote the first draft, all others participated in data collection, analysis and writing of the first draft. Monday Julius Rude revisited the first draft critically for key intellectual content and compiled all inputs of authors into the final version. Mosoka Fallah, Laura Skrip, Nuha Mahmoud, Monday Julius Rude and Trokon Yeabah: data collection, data analysis and read critically the manuscript, provided the necessary corrections and approved for submission. Kwuakuan Yealue, Okeibunor Joseph Chukwudi, Ambrose Talisuna, Adolphus Clarke and Ali Ahmed Yahaya: data collection, data analysis, read critically reviewed, corrected and approved the manuscript. Alex Gasasira, Tolbert Nyenswah, Ibrahima Socé Fall, Soatiana Rajatonirina, Esther Hamblion, Adolphus Clarke and Bernice Dahn read critically the manuscript and provided corrections, inputs and were involved in data analysis. All authors read and approved the final version of the manuscript and agreed upon submission for publication.

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Research

Enhancing laboratory capacity during Ebola virus disease (EVD) heightened surveillance in Liberia: lessons learned and recommendations

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Abstract

Introduction: following a declaration by the World Health Organization that Liberia had successfully interrupted Ebola virus transmission on May 9th, 2015; the country entered a period of enhanced surveillance. The number of cases had significantly reduced prior to the declaration, leading to closure of eight out of eleven Ebola testing laboratories. Enhanced surveillance led to an abrupt increase in demand for laboratory services. We report interventions, achievements, lessons learned and recommendations drawn from enhancing laboratory capacity.

Methods: using archived data, we reported before and after interventions that aimed at increasing laboratory capacity. Laboratory capacity was defined by number of laboratories with Ebola Virus Disease (EVD) testing capacity, number of competent staff, number of specimens tested, specimen backlog, daily and surge testing capacity, and turnaround time. Using Stata 14 (Stata Corporation, College Station, TX, USA), medians and trends were reported for all continuous variables.

Results: between May and December 2015, interventions including recruitment and training of eight staff, establishment of one EVD laboratory facility, implementation of ten Ebola GeneXpert diagnostic platforms, and establishment of working shifts yielded an 8-fold increase in number of specimens tested, a reduction in specimens backlog to zero, and restoration of turn-around time to 24 hours. This enabled a more efficient surveillance system that facilitated timely detection and containment of two EVD clusters observed thereafter.

Conclusion: effective enhancement of laboratory services during high demand periods requires a combination of context-specific interventions. Building and ensuring sustainability of local capacity is an integral part of effective surveillance and disease outbreak response efforts.

Introduction

One of the pillars of effective response to an outbreak is an efficient laboratory system [1]. Between March, 2014 [2, 3] and March, 2015 [4], Liberia battled what has been reported to be the largest Ebola virus epidemic in history [5, 6]. During this period, the country had up to 11 laboratories testing for Ebola Virus Disease (EVD) with support from the government of Liberia (GoL), the World Health Organization (WHO) and international partners [1]. On May 9 2015, the WHO made a declaration that Liberia had successfully interrupted transmission of Ebola virus, following a 42 day period since the death of the last EVD patient in that outbreak [4]. There, however, continued to be a risk of new importations of EVD into the country until transmission in the entire West African sub-region was stopped. The risk of a new emergence from an animal reservoir, importation, sexual transmission or a missed transmission chain led Liberia to enter a period of enhanced surveillance after the WHO declaration [7]. Subsequently, there occurred short-lived re-emergence of EVD in two small clusters involving six cases in June [8, 9] and three cases in November, 2015 [10]. Prior to the 2014 EVD outbreak in West Africa, there was no laboratory capacity to diagnose Ebola in Liberia. During the outbreak, laboratory capacity to diagnose EVD was established in-country and disease/outbreak confirmation became largely reliant on laboratory testing of whole blood, dead-body swabs, and post-mortem heart blood from suspected cases. Quantitative reverse transcription polymerase chain reaction (qRT-PCR) [11], the gold-standard diagnostic assay for detecting and quantifying Ebola virus, was predominantly used [12-14]. In 2015, the Xpert® Ebola assay for the GeneXpert platform (Cepheid, Inc., Sunnyvale, CA, USA) [15] an RT-PCR based assay, received emergency use authorization for Ebola diagnosis from the United States Food and Drug Administration [15]. Decreasing numbers of patients in the EVD holding and treatment centers prior to the 42-day period led to a rapid reduction in the number of laboratory requests [1]. This ultimately led to closure of eight EVD testing laboratories leaving three functional laboratories. Transition into enhanced surveillance led to a change from acute testing for clinical triage to surveillance testing [13], in which the threshold for the case definition was lowered to effectively demonstrate the absence of EVD in the local population [1]. When prevalence of a disease is low, there is a need to test more suspects (enhance surveillance) in order to rule out infection [1]. This resulted in an increase in the number of specimens thus increased demand on the efficiency and capacity of the remaining laboratories to test the exponentially increasing volume of specimens. We report the effect of interventions to boost laboratory capacity during the high demand period of enhanced EVD surveillance from May to December, 2015, and share lessons learned and recommendations for consideration in future laboratory capacity enhancement.

Methods

We analyzed laboratory and epidemiologic data generated daily between May and December, 2015. The Republic of Liberia is divided into five regions; North Eastern, North Central, South Central, South Eastern-A, South Eastern-B [16]; and consists of 15 administrative counties [3]. Approximately, 50% of Liberia's population lives in Montserrado County in which the country's capital city, Monrovia, is located [17]. Using archived data from WHO Emerging and Dangerous Pathogens Network (EDPLN) for EVD [18] hosted at WHO headquarters in Geneva, Liberia epidemiologic surveillance hosted at the Ministry of Health of Liberia, and individual laboratory log-books available at the respective laboratories, we obtained laboratory characteristics and trend of laboratory capacity before and after interventions. Interventions included: 1) establishing and developing EVD testing at two laboratories; 2) implementing new EVD diagnostic techniques not previously used in Liberia; 3) recruiting and training personnel in EVD molecular diagnostic procedures [13, 15]; 4) creating "partial testing shifts" to enable longer testing hours. Laboratories were characterized by name, location, date of establishment, date of closure, type, operating party, technology used to diagnose EVD and number of staff competent in EVD diagnostics.

Laboratory capacity was defined with respect to daily and surge testing capacity, turnaround time, number of EVD suspected specimens tested, and specimen backlog as a measure of the difference between the number of specimen received and number of specimen tested by the laboratories. Daily testing capacity was defined as the number of EVD suspected specimens tested per day. Surge testing capacity was considered to be the maximum number of EVD suspected specimens that could be tested per day. Turnaround time was defined as the time taken by each laboratory to generate and disseminate test results to the Ministry of Health leadership, from the time a specimen was received. All the six laboratories that conducted EVD diagnosis, at some point, during the period of enhanced surveillance were included in the analysis. Other laboratories involved in clinical or public health diagnostics but not EVD diagnosis were not considered. Using archives from the epidemiologic surveillance database, we extracted data on number of specimens received, and number of specimens tested per laboratory per day. We also obtained the number of specimen that did not get tested the same day they were received in a given laboratory and defined this as specimen backlog. Non normally-distributed continuous variables were summarized by median and interquartile range while categorical data were summarized as proportions. We reported the trend of number specimen tested and specimen backlog per month. Stata 14 (Stata Corporation, College Station, TX, USA) was used for all analyses. This was a retrospective analysis of data as part of documentation of best practices, and did not necessitate ethical approval; however, the use of data, analysis and report were approved by Ministry of Health, Liberia, and the WHO Liberia Country Office.

Results

Country laboratory coverage: at the start of enhanced surveillance in May 2015, Liberia had a total of four EVD testing laboratories (Table 1) representing 40% (2 out of 5) and 26.6% (4 out of 15) regional and county coverage, respectively (Figure 1). From 15th May until the peak of the enhanced surveillance in September-October, 2015, the country had three EVD testing laboratories following closure of one. This led to reduction in the overall country coverage to 20% (3 out of 15). These laboratories employed qRT-PCR technology for diagnosis (Table 1).

Table 1: characteristics of Ebola Virus Disease testing laboratories during enhanced surveillance in Liberia, 2015

EVD Laboratory	County	Date started Operating	Date closed	Facility type	Technology used	No. of staff	
						Median	Range
LIBR – NRL	Margibi	7-Aug-14	Open	Renovation	qRT-PCR GeneXpert	4	4,7
CDC-NIH	Montserrado	28-Sep-14	15-May-15	Renovation	qRT-PCR	0	0,0
Phebe Hospital	Bong	3-Oct-14	Open	Renovation	qRT-PCR GeneXpert	4	4,6
JFD Hospital	Nimba	5-Dec-14	Open	Renovation	qRT-PCR BioFire Film Array GeneXpert	4	2,6
ELWA III	Montserrado	28-Sep-15	Open	Mobile	GeneXpert	4	4,4
Redemption Hospital	Montserrado	3-Nov-15	Open	Renovation	GeneXpert	6	6,6

LIBR-NRL: Liberia Institute for Biomedical Research – National Reference Laboratory
qRT-PCR: Qualitative reverse transcriptase polymerase chain reaction
GeneXpert: Ebola GeneXpert Assay

Establishment of laboratories: to improve country-wide laboratory coverage, a mobile laboratory was successfully re-established at ELWA Ebola treatment unit (ETU), ELWA III laboratory, in Montserrado County and opened on 28th September, 2015 (Table 1). This restored the regional and county laboratory coverage to 40.0% and 26.6%, respectively (Figure 1). On 3rd November, 2015, Redemption Hospital clinical laboratory, located in Montserrado County, having completed the proficiency testing program, began testing whole blood for EVD, exclusively on samples from patients attending the hospital.

Implementation of new diagnostic techniques: due to a need to increase unit output, 10 GeneXpert machines with EVD testing capacity were implemented, with support from The foundation for innovative new diagnostics (FIND), WHO, academic consortium combating Ebola in Liberia (ACCEL) and United States Centers for Disease Control and Prevention (CDC), in Liberia. Four machines were installed at ELWA III laboratory in September 2015, one was installed at Redemption hospital laboratory in August 2015, two were installed at Phebe Hospital EVD laboratory in November 2015 and three was installed at Jackson F. Doe (JFD) Hospital EVD Laboratory in November 2015. The National Reference Laboratory (LIBR-NRL) partly used two GeneXpert machines that belonged to the National Institute of Health (NIH) research laboratory located at the Liberia Institute of Biomedical Research (LIBR) premises. Plans to establish a new EVD testing site, to use GeneXpert, in Maryland County,

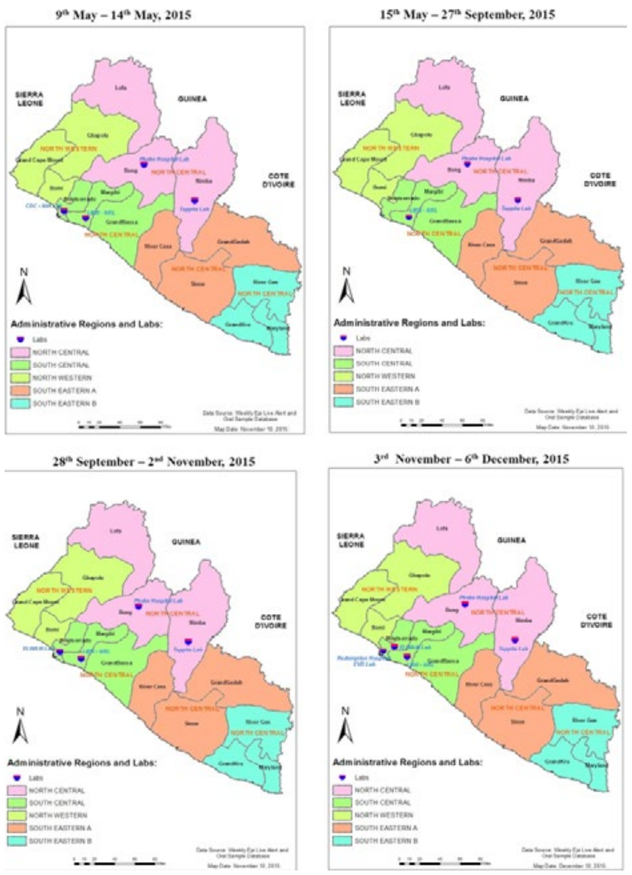

Figure 1: distribution of Ebola Virus Disease testing laboratories per county and administrative region during heightened surveillance in Liberia, 2015

South Eastern-B region, were pending implementation by the time of this report. Implementation of the OraQuick® Ebola Rapid Antigen Test (OraSure Technologies, Inc.) was in the process of being rolled-out at the time of enhanced surveillance and is therefore not discussed further.

Recruiting and training of personnel: between May and July 2015, there were 10 Liberian laboratory technicians competent in EVD diagnosis. Starting in August 2015, 16 technicians were recruited and trained in EVD molecular diagnostics. By October, 15 of them were competent in EVD diagnostic techniques. An additional 4 personnel were trained specifically on use of Xpert Ebola technology for Ebola diagnosis. By mid-October, there were up to 29 laboratory technicians proficient in EVD diagnosis (Table 1). International personnel with expertise in Ebola diagnosis were also recruited throughout the period to support diagnosis and training of local personnel. Earlier attempts to recruit more international experts by WHO and other partners, were not successful, due to the long procedures involved in international personnel recruitment and the lack of a database of experts to recruit from.

Implementing partial testing shifts: ELWA III laboratory established time-based shifts in which technicians reported and left work at different times, with considerable intersection between shifts. Phebe and JFD Hospital EVD laboratories had staff serving both the clinical and EVD laboratories. The work roster between the two laboratories was adjusted to cover the extended testing hours required for dedicated EVD testing. The Laboratory Manager would typically receive calls from a courier Riders for Health alerting him on the expected time of delivery of specimens. This notification would then trigger an action plan with assignment of staff to each stage of testing pipeline (sample inactivation, DNA extraction to RT-PCR or Biofire Film Array) to availing the results to the data manager. The staff assignment to a particular step or steps was based on their level of proficiency and comfort in carrying out the task in a timely manner and with accuracy regardless of the number of specimens. Bong EVD lab and NRI/LIBR established and published the cut-off time for sample reception and same day testing. The JFD EVD lab in Tappita normally received specimens towards the end of the official working hours so the laboratory maintained long opening hours. The Xpert Ebola Assay was introduced in these two laboratories when real-time EVD surveillance had been regained, that is to say, after all backlogged specimens had been tested and results disseminated). In addition, in July 2015, the JFD EVD laboratory began conducting semen testing for EVD, two days per week, in support of the National Men's Health Screening Program thus requiring further adjustment in the working schedule.

Overall impact: the median daily and surge testing capacity averagely increased from 35 and 102 to 77 and 134 specimens, respectively, excluding Redemption hospital EVD testing laboratory (Table 2). There was a 4-fold increase from daily to surge testing capacity (Table 2). The testing turnaround time had increased to 14 days by September 2015; however, it was reduced to within a day by the end of October 2015 (Figure 2). The total number of specimens tested for EVD increased from 651 specimens in May to 5,790 (88.9%) specimens in October (Table 3). An increasing specimen backlog (specimen that did not get tested for EVD within a 24 hours from the time of receipt at the respective laboratories) was observed from August 2015, with a peak of 896 specimens by mid-September 2015. The increase in the specimen backlog correlated with the increase in the total number of specimens received by the laboratories. This backlog decreased by end of October to 0 (zero) specimens, approximately three weeks prior to the November 2015 EVD flare in Liberia (Figure 2).

Table 2: daily and surge capacity, and turn-around time of Ebola Virus Disease testing laboratories during enhanced surveillance in Liberia, 2015

Laboratory	Daily Testing Capacity		Surge Testing Capacity/day		Turn-around Time in days	
	Median	Range	Median	Range	Median	Range
LIBR-NRL	84	60,120	140	132,175	3	0,14
Phebe Hospital	20	8,32	56	40,62	2	0,14
JFD Hospital	58	14,58	120	116,174	0	0,5
ELWA III	80	60,100	120	120,126	0	0,1
Redemption Hospital	1	0,9	16	16,16	0	0,1

LIBR-NRL: Liberia Institute of Biomedical Research – National Reference Laboratory
CDC-NIH EVD Laboratory was not included in this table because it was closed six days into enhanced surveillance

Table 3: number of Ebola Virus Disease suspected specimen tested and specimen backlog between May and December, 2015, in Liberia

Month	No. of specimen tested per day		Total No. of Specimen tested	Specimen backlog	
	Median	Range		Median	Range
May*	30	9,46	651	0	0,0
June	40	3,111	1208	0	0,0
July	60	28,111	1897	0	0,0
August	114	42,282	3982	0	0,266
September	183	65,281	5206	772	120,896
October	166	84,350	5790	442	0,819
November	125	49,264	3726	0	0,0
December*	148	42,312	947	0	0,0

*In this analysis, May starts from 9th to 31st and December starts from 1st to 6th. All other months are complete

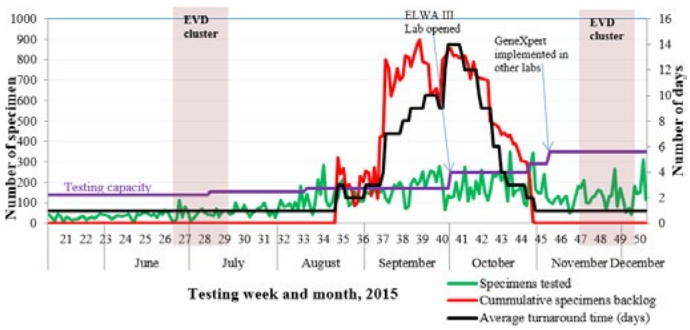

Figure 2: laboratory capacity indicating specific intervention points during enhanced surveillance in Liberia, 2015

Discussion

In our review of interventions used to boost laboratory capacity in Liberia following the 2014 and 2015 EVD outbreaks, we found that a combination of increasing the number of laboratories with EVD testing capacity by two, introduction of a new faster diagnostic technique, increasing the number of competent staff and increasing hours of testing, tremendously increased the overall laboratory output during enhanced surveillance and enhanced the country's response capacity and effectiveness. Closure of one of the EVD laboratories in mid-May, 2015, was a result of greatly diminished demand for laboratory services due to decreased numbers of patients in EVD holding and treatment units between February and March, 2015 [1]. Montserrado County was the ideal location for establishing new EVD testing sites because it is the most populous county, yielded the highest number of specimen, had one functional Ebola treatment unit (ETU) located at ELWA III hospital, and yet did not have an EVD testing laboratory [19]. Although testing capacity was limited in the South-Eastern area of Liberia (Maryland County) [16], it was not possible to establish another EVD testing site within a short time mainly due to lack of essential components of a field EVD testing laboratory including glove-box and limited human resources. However, this is achievable given more time to establish testing capabilities and trained workforce. GeneXpert was chosen as the diagnostic system to be implemented as it is a closed system with lower biohazard risk, offered an opportunity to increase laboratory output in a short time due to its shorter turn-around-time, it is less labor intensive compared to conventional qRT-PCR, requires minimal technical knowledge to operate and thus required less time to train technicians, and operates up-to 45 cycles allowing for more sensitive detection compared to the conventional RT-qPCR [15, 20].

Under the existing circumstances, it took some time for the impact of recruiting and training new local staff in EVD diagnostics to be felt as developing competence in qRT-PCR techniques takes approximately one and a half months or more if the trainees have no theoretical knowledge of molecular diagnostics. Upon gaining this competence, at approximately two and a half months from the time of recruitment of the additional staff, a boost in the overall output was registered. The international staff also provided a significant boost in EVD testing capacity. Establishing testing shifts at laboratories allowed for more productive testing hours. Establishment of testing shifts coupled with implementation more rapid Xpert Ebola assay allowed for increased testing output. It takes approximately 2 hours to obtain results using GeneXpert due to complete integration and full automation of the process, compared to 4 to 6 hours using conventional qRT-PCR that is affected by long pre-analysis stage (sample inactivation and extraction). LIBR-NRL and Phebe Hospital EVD laboratories had longer turn-around-time (Table 3) because they received more samples than other laboratories due to availability of more storage space for unprocessed specimens, and accessibility throughout the year. During the rainy season, accessibility of JFD hospital EVD laboratory was greatly compromised and therefore specimens were redirected to Phebe hospital EVD lab. This increased the volume of specimens received by the laboratory hence the increased turn-around-time observed. ELWA III lacked storage capacity for unprocessed samples and therefore always forwarded excess samples to LIBR-NRL. Following the outbreak of the second EVD cluster that originated in Margibi County [16] at the end of June, 2015 [8], the number of specimens received by laboratories greatly increased (Figure 2). This was attributed to more pro-active surveillance activities by all stakeholders. By mid-August 2015, the number of specimens had increased beyond the overall laboratory testing capacity thus yielding a cumulative specimen backlog. Having increased the number of laboratories, competent staff, working hours and implemented GeneXpert testing; the daily and surge EVD testing capacity increased thus increasing the number of specimen tested, decreasing the specimen backlog and yielded a reduction in testing turn-around time. We also observed that the number of specimens from EVD suspects collected from around the country, generally decreased as requests were sent to the health facilities to adhere to the screening criteria for EVD using the surveillance EVD case definition [1], and is believed to have partly contributed to the reduction in the specimen backlog. The new cluster of EVD cases observed in November, 2015 came approximately three weeks after clearing specimen backlog and at a time when laboratory capacity was sustainably efficient at approximately 350 specimens a day and turnaround time had been restored to less than 24 hours. This greatly facilitated the quick release of results which was essential to mobilize appropriate resources to contain the outbreak in a timely manner. As such, this cluster involved only three confirmed cases and it lasted approximately two weeks from admission of the first case to the ETU to discharge of the last case from the ETU. In addition, enhancing the laboratory capacity enabled reinstating of public health diagnostic services beyond testing for EVD especially for some of Liberia's Integrated Disease Surveillance and Response (IDSR) priority diseases. Re-instated capacity included measles and rubella in-country testing, Lassa fever and acute flaccid paralysis referral to international/regional reference laboratories. Recruitment and training of new technicians in EVD testing allowed for resumption of measles and rubella testing by the competent technicians who had previously been taken up with EVD diagnosis. Implementation of the EVD assay on the GeneXpert platform enabled integrated testing for tuberculosis, HIV viral load and HIV early infant diagnosis using the same instruments at JFD, Redemption and Phebe Hospitals.

Limitations

This is a documentation of best practices and not a research study, therefore, data used was obtained retrospectively. As a result, some data presented are estimates from a range recorded in the data sources. We have, however, included these ranges in the results to ensure accuracy of the data presented.

Conclusion

A combination of opportunity and supporting measures was adjusted to be responsive to the prevailing circumstances in Liberia with the aim of enhancing and maintaining of laboratory capacity for timely EVD diagnosis. These included leveraging available resources; maximizing the testing capacity at each laboratory using existing and new diagnostic platforms and supplies; emergency procurement of supplies and reagents to meet the demand; effective coordination and monitoring of testing at each laboratory; better forecasting and re-budgeting to stabilize the demand-testing equilibrium; and deploying additional staff. Enhancing and retaining local capacity and competencies to respond to any disease outbreak cannot be underscored. Given the possibility of reemergence of disease clusters or future outbreaks; a well-trained, competent and motivated workforce will enable continuity of laboratory services for disease surveillance, routine patient services and sustained vigilance for emerging and re-emerging disease threats. Data-driven decision trees should be used by all stakeholders to inform suspension or scaling down of essential laboratory services during a disease outbreak. This strategy is necessary to ensure that such services can be easily reinstated or re-scaled upwards during or after future disease outbreaks. Establishing key services during any given disease outbreak or crisis by governments, partners and other stakeholders should preferably be done by incorporating these services into already existing structures and involving local staff to enable sustainability and longevity. A robust supply chain and inventory system as well as budgeting and forecasting mechanisms by responsible parties to prevent shortage of essential reagents and other consumables are central to providing consistent and reliable diagnostic services.

What is known about this topic

- There is limited laboratory capacity especially in developing countries affecting timely diagnosis and therefore response to epidemic-prone diseases;
- Development of laboratory capacity in such settings usually takes a lot of time and requires a lot of resources.

What this study adds

- This paper demonstrates how a combination of context specific interventions can rapidly enhance laboratory capacity in a cost-effective manner, especially during times of abrupt high demand.

Competing interests

The authors declare no competing interest.

Authors' contributions

Victoria Katawera contributed to conception, design, data acquisition, analysis, interpretation, drafting and critically revising the paper for important intellectual content, and has provided final approval of the version to be published. Henry Kohar, Nuha Mahmoud, Philomena Raftery, Christine Wasunna, Ben Humrighouse, Patrick Hardy, John Saindon, Randal Schoepp, Monear Makvandi, Lisa Hensley, Orla Condell, Laetitia Gahimbare, Gene Olinger, Desmond Williams, Alex Gasasira contributed to design, data acquisition, critically revising the paper for important intellectual content, and have provided final approval of the version to be published. Kara Durski, Shalini Singaravelu, Dhamari Naidoo, Pierre Formenty contributed to data acquisition, analysis, critically revising the paper for important intellectual content, and have provided final approval of the version to be published. Francis Kateh, Peter Nsubuga, Tolbert Nyenswah, Sheick Oumar Coulibaly, Okeibunor Joseph Chukwudi, Ambrose Talisuna, Ali Ahmed Yahaya, Soatiana Rajatonirina, Bernice Dahn, Ibrahima Socé Fall contributed to design, critically revising the paper for important intellectual content, and have provided final approval of the version to be published.

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Research

Strengthening healthcare workforce capacity during and post Ebola outbreaks in Liberia: an innovative and effective approach to epidemic preparedness and response

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Abstract

Introduction: the 2014-2016 Ebola virus disease (EVD) outbreak in Liberia highlighted the importance of robust preparedness measures for a well-coordinated response; the initially delayed response contributed to the steep incidence of cases, infections among health care workers, and a collapse of the health care system. To strengthen local capacity and combat disease transmission, various healthcare worker (HCW) trainings, including the Ebola treatment unit (ETU) training, safe & quality services (SQS) training and rapid response team (RRT), were developed and implemented between 2014 and 2017.

Methods: data from the ETU, SQS and RRT trainings were analyzed to determine knowledge and confidence gained.

Results: the ETU, SQS and RRT training were completed by a total of 21,248 participants. There were improvements in knowledge and confidence, an associated reduction in HCWs infection and reduced response time to subsequent public health events.

Conclusion: no infections were reported by healthcare workers in Liberia since the completion of these training programs. HCW training programmes initiated during and post disease outbreak can boost public trust in the health system while providing an entry point for establishing an Epidemic Preparedness and Response (EPR) framework in resource-limited settings.

Introduction

The 2014-15 Ebola outbreak in West Africa had a devastating effect on the healthcare system, in particular for healthcare workers (HCWs). HCWs were up to 32 times more likely to be infected with Ebola than the general population and two-thirds of infected HCWs died [1, 2] .Multiple factors contributing to EVD transmission among HCWs included deficiencies in administrative, engineering and environmental regulations, overcrowding of public hospitals and unsafe employment conditions. A major driver was the limited infection prevention and control (IPC) capacity in West Africa at the time of the outbreak [1]. Thus, under the incident management system (IMS) of the ministry of health and social welfare (MOHSW) [3], the Case Management technical pillar and the National IPC Task Force took the lead to address these IPC capacity gaps through training [4]. This was done in collaboration with international partners and local non-governmental organizations (NGOs). The training of HCWs in IPC was initiated at the peak of the outbreak as a means to enhance in-country epidemic preparedness and response (EPR). Ultimately, there were two large-scale training initiatives implemented for HCWs during the 2014-2015 Ebola outbreak. These included the keep safe, keep serving (KSKS) and the healthcare workers in Ebola treatment unit program (ETU). The IPC-focused KSKS curriculum [5] was developed for non-ETU settings and was implemented with over 4000 HCWs [6].

Once Liberia was declared free of human-to-human Ebola transmission in May 2015, the government's focus shifted to sustaining a "resilient zero". This characterized the third phase of the Ebola response [7] emphasizing health system recovery and strengthening, as reflected in the development of Liberia's investment plan for building a resilient health system (2015-2021) [8]. The plan aimed to ensure universal health coverage, guarantee health security, and improve health outcomes, while complementing the national health policy and plan (NHPP) (2011-2021). Enhancing safe and high-quality health services through the adherence of HCWs to appropriate clinical care practices was identified as a main investment area. HCWs trained during KSKS on the "No touch policy" had to be reoriented to interact with their patients using standard care procedures, enhanced with reasonable IPC measures- that is, they required an understanding of the importance of implementing IPC measures at all times (known as standard precautions), not just during outbreak settings. Moreover, the EVD crisis had resulted in low confidence in the health system among HCWs and the general public. To address these priorities and issues, the build back better health system strategy (BBBHSS) was developed [9]. This included a training component which became known as safe & quality service (SQS).

By 2016, public confidence in their health care system had been re-established [10]. The MOH and the then newly launched national public health institute of Liberia (NPHIL) undertook the transition from rehabilitation and recovery mode to strengthening epidemic preparedness. To improve, standardize and decentralize preparedness capacity, rapid response teams (RRT) were formed in all 15 counties. Additionally, a national RRT was established to provide support to counties during large public health events. RRT training packages were developed, rolled out and then tested through simulations in each county. The WHO disaster risk management cycle which informs public health emergencies preparedness describes the different phases that Liberia experienced with the EVD outbreak [11]. Typically, the pre-disaster (and required trainings) precedes the post-disaster phases; in Liberia, the cycle was reversed. Here we describe the processes for developing and implementing the HCWs in Ebola treatment unit program during the EVD outbreak response, the SQS training during the post-EVD recovery period and the RRT training undertaken in post-EVD preparedness phase in preparation for future outbreaks. We also present results from pre-and post-tests administered to HCWs who participated in any of the three trainings as a measure of their impact on knowledge and attitudes. These trainings engaged over 21,000 national and international healthcare workers in capacity building to enhance the use of standard and transmission-based prevention measures.

Methods

Overview of the healthcare workers in ebola treatment unit: the objectives of the training on healthcare workers in Ebola treatment unit involved ensuring HCW safety, improving effectiveness and quality of care for patients in the Ebola treatment units (ETUs), and fighting the epidemic through patient care and isolation to prevent further spread. The package, an adoption and adaptation of existing WHO Ebola response training packages [12], included IPC (standard and additional precautions), EVD case management, safe burials, amongst other key components required to work in an ETU (Table 1). The 8 days skills-oriented training course was divided into a clinical and non-clinical stream in a 3-phase format: classroom-based didactic training (phase I), simulated patients (recovered Ebola patients) in a mock ETU (phase 2), and mentored introduction seeing patients in an actual ETU (phase 3). On completion and passing the post training exam participants were awarded certificates [13]. The MOH/IMS mandated the training as a prerequisite for any national or international Ebola outbreak responder planning to work in an ETU. As the training workforce and needs increased, mobile teams were formed by various partners to support and build county health workforce capacity in all the 15 counties. Participants were administered nine-item pre- and post-test questionnaires to assess change in confidence and knowledge upon exposure to the training.

Table 1: healthcare workers in Ebola treatment unit training content

Category	Phase 1 and 2	Phase 3
General modules	Overview of Ebola Strategies to stop EVD transmission Infection Prevention and Control PPE for Ebola HCW preparedness for work and Heat stress management	Introduction to ETU (layout, wards, and patient flow) ETU Standard Operating Procedures PPE Demonstration Admissions and discharge protocol
Clinical stream	Screening and overall ETU organization Clinical care for Ebola patients Collection, packaging, and transportation of EVD samples	Ward introduction Triage Case management (assessment of fluid and antibiotic needs, IV line placements, medication protocols, prescriptions, and abbreviations) Liberia Ebola clinical guidelines Lab testing
Non-Clinician stream	Principles of Cleaning and Disinfection, Chlorine preparation Environmental Cleaning Waste Management Dead body Management	Cleaning and disinfection in the low and high-risk zones Spraying Laundry management Dead body management Incineration

Overview of the SQS training package: the SQS training package, an MoH and WHO initiative, provided an integrated approach to restoring and building healthcare workers confidence, knowledge and skills for delivery of safe and quality health services. The core components of this training package included psychosocial support (PSS), Infection Prevention & Control (IPC), EVD management, surveillance and clinical emergency management (Figure 1). Initially, technical working groups were formed per technical area to review, adopt, and adapt existing training materials (e.g. integrated management of adolescent and adult illness (IMAI) district clinical manual [14], WHO hand hygiene guidelines [15], WHO standard precautions [16]. Technical guidelines for integrated disease surveillance and response (IDSR) [17]). This process included iterative versions of the curriculum and a pilot in Lofa County. The result of this process was a locally relevant curriculum that could be used for both clinical and non-clinical workers that accounted for low literacy rates among non-clinical workers such as through an oral examination for this group. The national rollout was initiated with County health teams (CHTs) recommending county-level implementing partners; partners recruited were those already involved in EVD response in the country. This was followed by a central MoH-WHO training of trainers (ToT), county level ToTs and finally the frontline health workers' training. In collaboration with the CHT, the lead implementing partner was responsible for county level training coordination and implementation, as well as managing other county based implementing partners. At the end of 2015, MOH in collaboration with WHO held a meeting for all implementing partners to discuss results, lessons learnt and recommendations.

Overview of the rapid response team training and simulations: NPHIL in collaboration with the epidemic preparedness and response (EPR) consortium (consisting of the international rescue committee, international organization on migration, international mercy corps, save the children) and WHO developed the county (sub-national) rapid response team (CRRT) training curricula and simulations in mid-2016 based on the integrated disease surveillance and response guidelines, the national epidemic and preparedness plan 2016, experiences and lessons learnt from the various outbreaks [18]. Modules included introduction to key concepts of IDSR, EPR and RRT, composition, roles and responsibilities of CRRTs. The two-day county simulations were designed to assess Ebola response capacity and gain outbreak experience in a safe environment. The exercise was undertaken at the health facility, isolation unit, district, and county levels: day one of the simulation was a functional exercise which assessed the capacity of the health facility staff, isolation unit staff, and the district health team (DHT). Day two of the simulation was a table top county integrated management system (IMS) exercise which evaluated the CHT response capacity. This was followed up in 2017 by the national RRT (NRRT) training package development, an amalgamation of the county RRT curriculum, and adaption of the WHO National RRT Training package [19]. On 29th May 2017, National level underwent RRT training that was divided into two parts: an orientation and two-day real-time simulation. The simulation involved mock patients presenting at various health facilities in Montserrado County, testing the entire response system: from health facility to county notification to activation and deactivation of national response team, and ended at the newly established Redemption Hospital 9-bedded integrated severely infectious treatment unit (InSitu); Liberia's first official isolation facility.

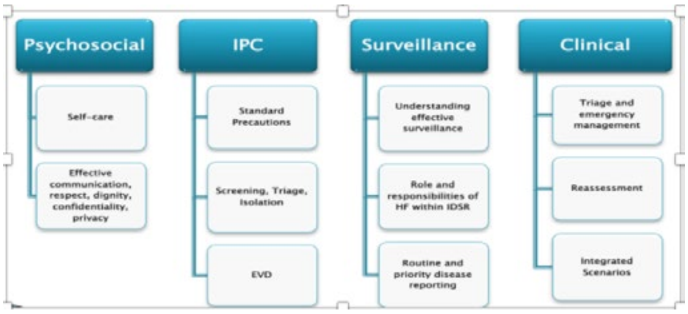

Figure 1: safe & quality services (SQS) training package content

Study design and data collection: survey data on confidence...

Data analysis: data sources include pre and post tests given to ETU and SQS training participants and programmatic database for the RRT training. Frequencies and percentages were used to describe data collected on the number of participants, both overall and at the county-level for the ETU and SQS training programs. For the ETU training, changes in confidence and knowledge between pre-and post-training tests were analyzed using paired t-tests. The analysis sample was limited to individuals who completed both pre- and post-tests. Results of the statistical tests were reported with the corresponding mean changes and 95% confidence intervals. A p-value < 0.05 was considered statistically significant.

Ethical considerations: confidentiality and anonymity of participants have been ensured.

Results

Over a period of two and a half years (from September 2014 through to April 2017), there were 21,248 participants trained in the ETU, SQS and RRT trainings, with individuals participating in multiple programs.

Healthcare workers in Ebola treatment unit

Who was trained and where training occurred: the Ebola healthcare worker training was conducted by seven organizations in Liberia-MOH in collaboration with WHO (WHO/MOH), International Organization for Migration (IOM), Medecin Sans Frontieres (MSF) Belgium, United States of America department of defense (US DoD), international medical corps (IMC), ASPEN medical and samaritan purse (Figure 2). For national HCWs, county coverage varied with the highest being from Montserrado (approximately 60 % of all HCWs trained), compared to other counties (which averaged 20-30%).

Numbers trained: from September 2014 to March 2015, a total of 5518 national and international health care workers were trained in the Healthcare Workers in Ebola treatment unit program; international HCWs contributed 16.7% (n = 923) and national HCWs contributed 83.3% (n = 4595) of total trained. The international cohort included more than 30 international partners or foreign medical teams (FMTs) including ECOWAS/African Union (AU), Bangladesh armed medial core, Cuban medical team, China armed forces, German red cross/armed forces, ARC, Heart to Heart International, IOM, International Rescue Committee (IRC), Save the Children, Partners In Health (PIH), US DOD, Swedish Civil

Figure 2: healthcare worker Ebola treatment unit (ETU) training coverage by partners and counties

Contingencies Agency, amongst others. The trainees consisted of slightly more non-clinicians (58%) than clinicians (42%). Trained participants supported not only clinical care delivery teams within ETUs, but also county training teams and critically re-opening and establishing IPC measures (especially linking to triage) in routine healthcare facilities. The best performing nationals were recruited and mentored as facilitators upon successful completion of the training to build national capacity for future outbreaks, trainings and refreshers.

Pre-and post-training knowledge assessment: each cohort undertook a pre- and post-test assessment of their knowledge in the key taught areas. Pre-training scores were particularly low for PPE donning and doffing, EVD Clinical care and EVD laboratory diagnosis. Both clinicians (n = 188) and non-clinicians (n = 149) showed statistically significant improvements in knowledge on clinical care and IPC concepts, as measured by the 9-item pre-and post-test questionnaires (both $p < 0.001$). The average change in knowledge was significantly higher for clinicians than for non-clinicians ($p = 0.006$); specifically, the mean changes between pre- and post-test were 28.2 and 22.7-point changes for clinicians and non-clinicians, respectively (Figure 3).

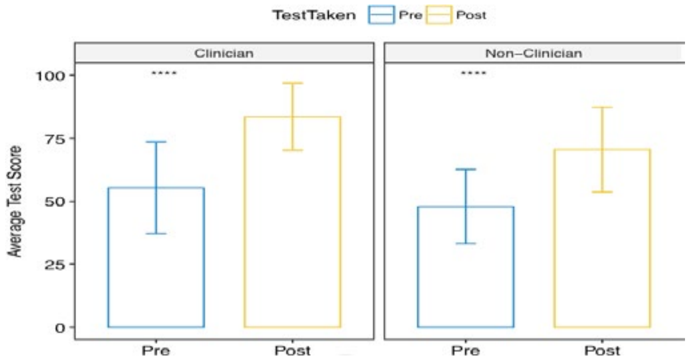

Figure 3: average results of pre- and post-test assessments for ETU training participants

Healthcare worker infections: an associated finding that occurred during the training period was the downward trend in EVD healthcare worker infections between October 2014 and March 2015; healthcare worker infection rate was 9% by October 2014 and had dropped to 1% by January 2015 [1]. Furthermore, after the conclusion of training in March 2015, no healthcare worker infections were reported among those exposed to the confirmed cases despite the resurgence of Ebola cases in June and November 2015, and April 2016 (Figure 4).

SQS Training

Who was trained and where training occurred: SQS was rolled out in all 15 counties by the respective CHTs in collaboration with the assigned implementing partners (19 in total; with a minimum of one and maximum of seven implementing partners per county).

Numbers trained: a total of 14,913 HCWs across all 15 counties were trained; 693 facilitators, 4099 clinicians, and 10,121 non-clinicians. The greatest number of trainees came from Montserrado, followed by Nimba and Bong, which are the three most populous counties. The ratio of trainees to facilitators varied across counties.

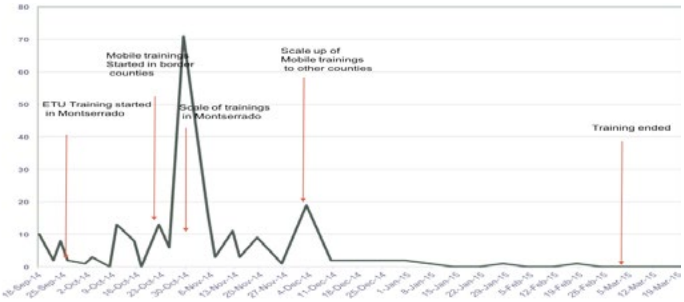

Figure 4: HCWs Ebola Virus Disease infection trend September 2014-March 2015

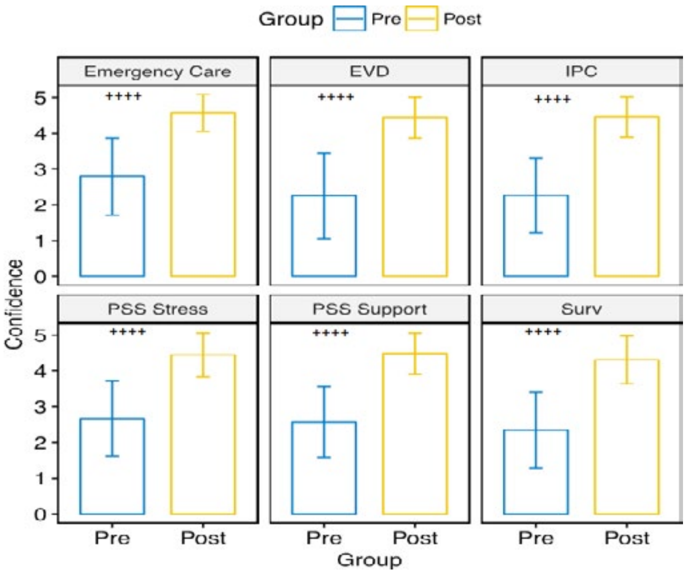

Figure 5: pre- and post-test confidence scores for clinician subgroups who had the SQS training; bar height represents mean scores at pre- (blue) or post-test (yellow), given a 5-point Likert scale measuring confidence in various areas of the health sector; error bars reflect one standard deviation above and below the mean; mean confidence score in all areas significantly increased between pre- and post-test (++++p < 0.001)

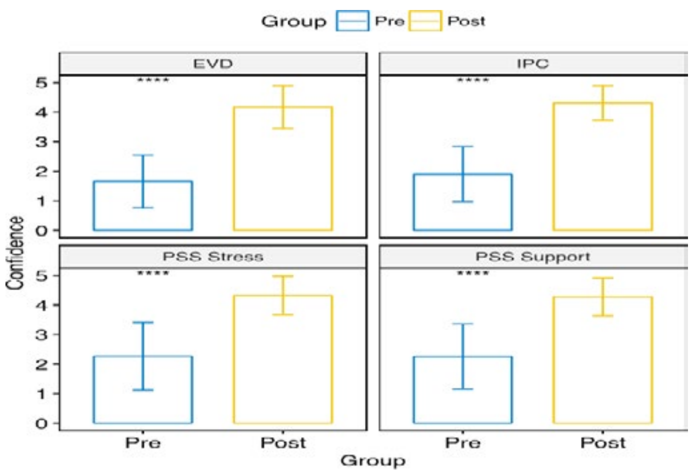

Figure 6: pre-and post-test confidence scores for non-clinician subgroup who had the SQS training; bar height represents mean scores at pre- (blue) or post-test (yellow), given a 5-point Likert scale measuring confidence in various areas of the health sector; error bars reflect one standard deviation above and below the mean; mean confidence score in all areas significantly increased between pre- and post-test (++++p < 0.001) clinicians were tested on two additional indicators, relative to non-clinicans

Pre-and post-training knowledge assessment: each county-level cohort undertook a pre-and post-test assessment of their knowledge in the key subject areas. Pre-existing knowledge tended to be higher in the non-clinician cohort than in the clinician cohort. The knowledge gained among clinicians ranged from 15% to 48%; the highest gain was in the EVD, and surveillance modules and the lowest was in the IPC module. The knowledge gained among non-clinicians ranged from 14% to 23%; the highest gain was in the IPC module, and the lowest was in the EVD module. Participants ranked their confidence in key aspects of health system using a 1-5 Likert scale. Confidence in the areas of emergency medicine, EVD, IPC, psychosocial and surveillance increased significantly (all $p < 0.001$) between pre-test and post-test for both clinician and non-clinician groups (Figure 5 and Figure 6). Mean changes for confidence in emergency medicine and surveillance were 1.78 (95% CI: 1.60-1.96) and 1.96 (95% CI: 1.79-2.13), respectively, for clinicians. Mean changes for confidence in EVD, IPC, psychosocial support, and psychosocial stress were 2.18 (95% CI: 2.00-2.36), 2.19 (95% CI: 2.01-2.37), 1.92 (95% CI: 1.77-2.07), and 1.78 (95% CI: 1.60-1.96), respectively, for clinicians. For non-clinicians, mean changes for confidence in EVD, IPC, psychosocial support, and stress were 2.51 (95% CI: 2.40-2.63), 2.41 (95% CI: 2.30- 2.51), 2.02 (95% CI: 1.89-2.14), and 2.05 (95% CI: 1.93-2.18), respectively.

RRT Training and Simulations

Who was trained and where training occurred: for the CRRT, the county and district health teams were trained in each of the 15 counties and 91 districts respectively in June and July 2016. National RRT training and simulation were held in Monrovia in May 2017.

Numbers trained: for the CRRT, 53 experienced outbreak personnel were initially trained as trainers, whom facilitated the county RRT training rollout for which a total of 792 individuals participated from all respective counties (93% coverage of targeted number). For the NRRT training there were 25 participants with representation from the various response pillars (epi-surveillance, case management, psychosocial, etc.)[20].

Pre-and post-training knowledge assessment: the results of the pre-tests administered to all participants in all 15 counties ranged from approximately 50-62%, while the post-test results ranged from 80-90%.

Simulation findings: observations from the 15 county simulations undertaken included: variable response capacity across counties (linked to previous EVD outbreak experience), the biggest gaps were at health facility level (inappropriate screening, isolation and case management) and district level (fragmented response), and county IMS was typically the strongest portion of the response, although pillars didn't have a full understanding of roles and responsibilities. Key observation at the NRRT simulation was that participants were familiar with some but not many of the outbreak response processes. Key gaps identified included: information management via the different response levels, lack of familiarization of forms needed to be completed during an alert case, infection prevention and control measures (especially doffing), correct referral pathways, suspect case definitions and clinical management.

Discussion

Pre-EVD, no formal EPR trainings were available in Liberia; as the EVD outbreak escalated in 2014 a dire need for HCWs capacity and confidence building was identified. To address this, a HCW training programme was initiated by the Ebola IMS using available resources for outbreak response and at the same time strengthening preparedness capacity. The implementation of these training programs led to heightened knowledge, skills and confidence amongst healthcare workers. There was a drop in HCWs infection following the introduction of the ETU training and in the post-EVD period no HCWs infections have been documented. In the post-EVD period, Liberia has experienced improvements in epidemic preparedness and response, as has been demonstrated by reduced response time to public health events: in 2016, out of 32 outbreaks, 44% (14/32) were responded to within 48 hours, whereas in 2017 there were 39 outbreaks of which 82% (32/39) were responded to within 48 hours [21]. The progress made by Liberia in epidemic preparedness and response can be attributed to capacity building in surveillance, laboratory diagnostics, case management, and workforce development including IPC that were achieved through training programs such as ETU, SQS and RRT. As a result of the trainings, guidelines have been developed and referenced during subsequent outbreaks and refresher training. This strategy corresponds with outbreak control measures implemented in experienced EVD countries such as Uganda [22]. The undertaking of the ETU and SQS training programs in the context of a widespread outbreak of a disease, highly transmissible in the event of direct contact and without well-established curative treatment, is noteworthy. The successful implementation was attributable to national and county MOH leadership and coordination, multi-stakeholder involvement with clear roles and responsibilities, a phased approach, iterative process of adapting training material based on implementation feedback, external quality assurance and resource availability.

A limitation of this study is that the reduction in HCWs infections following the ETU training cannot be attributed directly to the training only, due to concurrent in-country programs such as the influx of PPE supplies, which allowed for increased use independent of the training. Another weakness is the latct of data, particularly on RRT training, limited data analysis and what can be extrapolated from that specific training. These findings are consistent with the limited published literature [23]. this study validates that training programmes can be effectively developed and implemented during a crisis. Rapid implementation of large-scale training such as the SQS is possible with strong leadership, coordination and collaboration between the Ministry of Health (at all levels) and implementing partners. However, institutionalizing training in pre-service and academic institutions, and consistent in-service supportive supervision and simulations, and table-top exercises. In addition, for surge capacity it is critical to maintain an updated are key for sustainability and improve outbreak detection [3, 24].

Conclusion

These training programmes, which were made possible thanks to EVD outbreak response resources, led to heightened knowledge, skills and confidence amongst healthcare workers, and more prompt response time to subsequent public health events. Training is critical for strengthening local capacity to contain outbreaks and prevent future ones, improve quality of care, and increase overall knowledge. Moreover, the timing of trainings and the use of refresher trainings should be part of an integrated programme to ensure up-to-date competencies, readiness and sustainability.

What is known about this topic

- Healthcare workers training, including refresher training, during outbreaks is key to controlling disease transmission, protecting healthcare workers, patients and improving confidence in the healthcare system.

What this study adds

- There is have been no healthcare workers' infection in Liberia since completion of these training programs;
- Training programmes initiated during and post outbreaks can be leveraged as an entrance point to establishing an epidemic preparedness and response framework (including political buy-in and funding).

Competing interests

The authors declare no competing interest.

Authors' contributions

All authors read and agreed to the final version of this manuscript and equally contributed to its content and to the management of the case.

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Research

Integrated disease surveillance and response implementation in Liberia, findings from a data quality audit, 2017

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Key words: Data quality assessment, disease surveillance information system, simple random sample, data accuracy, reliability and credibility, multi-stage cluster sampling, completeness, and timeliness integrated disease surveillance and response, health management information system (HMIS)/district health informative system two (DHIS2) database, case investigation forms and eDEWS

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Abstract

Introduction: in spite of the efforts and resources committed by the division of infectious disease and epidemiology (DIDE) of the national public health institute of Liberia (NPHIL)/Ministry of health to strengthening integrated disease surveillance and response (IDSR) across the country, quality data management system remains a challenge to the Liberia NPHIL/MoH (Ministry of health), with incomplete and inconsistent data constantly being reported at different levels of the surveillance system. As part of the monitoring and evaluation strategy for IDSR continuous improvement, data quality assessment (DQA) of the IDSR system to identify successes and gaps in the disease surveillance information system (DSIS) with the aim of ensuring data accuracy, reliability and credibility of generated data at all levels of the health system; and to inform an operational plan to address data quality needs for IDSR activities is required.

Methods: multi-stage cluster sampling that included **stage 1:** simple random sample (SRS) of five counties, s**tage 2:** simple random sample of two districts and **stage 3:** simple random sample of three health facilities was employed during the study pilot assessment done in Montserrado County with Liberia institute of bio medical research (LIBR) inclusive. A total of thirty (30) facilities was targeted, twenty nine (29) of the facilities were successfully audited: one hospital, two health centers, twenty clinics and respondents included: health facility surveillance focal persons (HFSFP), zonal surveillance officers (ZSOs), district surveillance officers (DSOs) and County surveillance officers (CSOs).

Results: the assessment revealed that data use is limited to risk communication and sensitization, no examples of use of data for prioritization or decision making at the subnational level. The findings indicated the following: 23% (7/29) of health facilities having dedicated phone for reporting, 20% (6/29) reported no cell phone network, 17% (5/29) reported daily access to internet, 56.6% (17/29) reported a consistent supply of electricity, and no facility reported access to functional laptop. It was also established that 40% of health facilities have experienced a stock out of laboratory specimens packaging supplies in the past year. About half of the surveyed health facilities delivered specimens through riders and were assisted by the DSOs. There was a large variety in the reported packaging process, with many staff unable to give clear processes. The findings during the exercise also indicated that 91% of health facility staff were mentored on data quality check and data management including the importance of the timeliness and completeness of reporting through supportive supervision and mentorship; 65% of the health facility assessed received supervision on IDSR core performance indicator; and 58% of the health facility officer in charge gave feedback to the community level.

Conclusion: public health is a data-intensive field which needs high-quality data and authoritative information to support public health assessment, decision-making and to assure the health of communities. Data quality assessment is important for public health. In this review completeness, accuracy, and timeliness were the three most-assessed attributes. Quantitative data quality assessment primarily used descriptive surveys and data audits, while qualitative data quality assessment methods include primarily interviews, questionnaires administration, documentation reviews and field observations. We found that data-use and data-process have not been given adequate attention, although they were equally important factors which determine the quality of data. Other limitations of the previous studies were inconsistency in the definition of the attributes of data quality, failure to address data users' concerns and a lack of triangulation of mixed methods for data quality assessment. The reliability and validity of the data quality assessment were rarely reported. These gaps suggest that in the future, data quality assessment for public health needs to consider equally the three dimensions of data quality, data use and data process. Measuring the perceptions of end users or consumers towards data quality will enrich our understanding of data quality issues. Data use is limited to risk communication and sensitization, no examples of use of data for prioritization or decision making at the sub national level.

Introduction

Liberia and other countries in the WHO African Region continue to be affected by inconsistent data at all levels of the surveillance system, which may affect the implementation of the IDSR in a negative manner. Public health data are used to monitor trends in the health and wellbeing of the community and of health determinants. Also, they are used to assess the risks of adverse health effects associated with certain determinants, and the positive effects associated with protective factors. The data informs the development of public health policy and the establishment of priorities for investment in interventions aimed at modifying health determinants. They are also used to monitor and evaluate the implementation, cost and outcomes of public health interventions, and to implement surveillance of emerging health issues [1]. Thus, public health data can help public health agencies to make appropriate decisions, take effective and efficient action, and evaluate the outcomes [1, 2]. For example, health indicators set up the goals for the relevant government-funded public health agencies [3]. Data verification was conducted at selected sites by reviewing data sources that include but not limited to, Supportive Supervision Reports, Outbreak Reports, Maternal and Neonatal Death Surveillance and Response Reports, Assessment Report (including family health database), IDSR aggregate and line-list database, Health Management Information System (HMIS)/District Health Informative System two (DHIS2) database, Case investigation forms and eDEWS assessment reports within the period of January-December, 2016. Data quality in public health has different definitions from different perspectives. These include: "fit for use in the context of data users, timely and reliable data essential for public health core functions at all levels of government, accurate, reliable, valid, and trusted data in integrated public health informatics networks" [4]. The government of Liberia has been gradually strengthening the national disease surveillance system until the country was hit by the unprecedented outbreak of Ebola virus disease (EVD) in 2014; an epidemic that virtually collapsed the health system. The health system's weakness was revealed as the result of its inability to detect, investigate and respond to the epidemic in a timely manner; during the outbreak, there was increased deaths and fatality rates among health workers that reflects a weakness in the public health system. The post EVD assessment revealed major weaknesses and the need to establish a national public health institute to focus on building a resilient public health system in the country [1]; ensure preparedness and response; Source of technical expertise in generating, analysing and interpreting public health data in the health sector for the formation of health policies; catalyst for the implementation of international health regulations (IHR, 2005) that are both; sustainable and suitable for the local context; exclusively devoted to overcoming public health challenges and improving the population consciousness on health threats; surveillance, detection, response, and research and generating information to allocate resources for maximal public health benefits. The IDSR system (guidelines) was revitalized in 2015 and 2016 as per lessons learned from the EVD outbreak to serve as a guide for improving early detection, and preparedness activities, improve timely investigation and response, and foster integration to strengthen national cross-sectoral capacity for collaborative disease surveillance and epidemic preparedness, thereby addressing systemic weaknesses within the animal, human and environmental health sectors that hinder effective disease surveillance and response and ensure efficient use of resources [5] The establishment of the national public health institute of Liberia and development of the national investment plan for health resulted in structural reforms-(e.g. the divisions infectious disease and epidemiology (DIDE), division of environmental health were migrated from the MOH and placed under the NPHIL to give examples) in the health sector geared towards a fit for purpose, motivated and productive health work force, re-engineered health infrastructures, and strengthen public health surveillance, epidemic preparedness, diagnostics and response capacity across all levels. The republic of Liberia suffered a devastating civil war which lasted from 1999 - 2003 [6]. The 14 years of civil war destroyed the economy, infrastructures and the health care delivery system such as the hospitals, clinics, electricity, and other essential resources [7, 8]. Liberia was known to be one of countries with the poorest health system in the sub region [4]. As part of the attempts to restore the public health infrastructure of the country, the WHO integrated disease surveillance and response system (IDSR) was adopted in 2004 [9]. The IDSR strategy is an integrated approach for improving public health surveillance and response and promotes the rational use of resources [10]. It is aimed at improving the use of information for early detection of outbreaks and timely response. In the African region, IHR (2005) is implemented in the context of IDSR. The implementation of IDSR in Liberia concentrated on case detection, notification, investigation and confirmation, outbreak preparedness and response, data management and analysis, monitoring and evaluation and support functions (laboratory services, supportive supervision and training based on identified gaps) [11] -prior to the EVD epidemic, the IDSR implementation was limited to AFP surveillance and was not robust in timely detection, investigation, and reporting -(there was no standard data collection and reporting tool at the sub national levels of the health system). In view of this, the timeliness and completeness of the IDSR reports was low, inadequate case detection, reporting, investigation and response to outbreaks, no or inadequate documentation of IDSR data and counties were not using surveillance data for public health actions. It was also observed that data management, and analysis at the sub-national level was very low [12]. The MoH/NPHIL in collaboration with the World Health Organization (WHO) and other partners implemented surveillance activities in all counties and districts, 769 health facilities, and implemented community event-based-surveillance in half of the country to increase for 14 immediately reportable conditions. Over 2,000 health workers were trained in IDSR with at least two officers from each health facility. The early warning and IDSR data is published weekly by the division of infectious disease and epidemiology (DIDE) of the national public health institute of Liberia (NPHIL)/Ministry of Health (MoH). This bulletin highlights numbers of immediately reportable diseases as well as reporting coverage by health facilities, districts and counties during each epidemiologic week. The information is generated from surveillance activities captured by surveillance officers at district and county levels inclusive of laboratory. Over a period of time, the reporting and analysing of IDSR data has improved but the data source remains the county surveillance officers and laboratory only. Efforts are being made in coordination and active involvement of parallel divisions like family health, expanded programme on immunization, and health management evaluation and research at both national and county level to contribute in the collection, correlation and analysing of surveillance data for the priority diseases. In ensuring reliability, quality and credibility of IDSR data generated from the grass root health facilities, the MoH division of infectious disease and epidemiology along with implementing partners commenced the process IDSR data quality audit across the country in selected counties and health facilities. The objective of this paper is to document data quality, identify technical, managerial, and organizational determinants within the Liberian context and inform an operational plan to address data quality needs for IDSR activities.

Methods

The data quality audit was conducted in five phases: phase one focused on the preparatory activities, phase two involved desk review of reported data, phase three activity was field assessment, during phase four, an action plan was developed, and phase five focused on the compilation of data, report writing, and results dissemination to stakeholders. This exercise was carried out from January 2-April 17, 2018 (Table 1).

Sampling Method: multi-stage cluster sampling that included stage 1: simple random sample (SRS) of five counties, stage 2: SRS of two districts and stage 3: SRS of three health facilities. Pilot assessment was done in Montserrado County with Liberia institute of bio medical research (LIBR) inclusive. A total of thirty (30) facilities was targeted, twenty-nine (29) of the facilities were successfully audited: one hospital, two (2) health centers, twenty-six (26) clinics and respondents included: health facility surveillance focal persons, ownal surveillance officers (ZSOs), district surveillance officers (DSOs) and County surveillance officers (CSOs) (Figure 1).

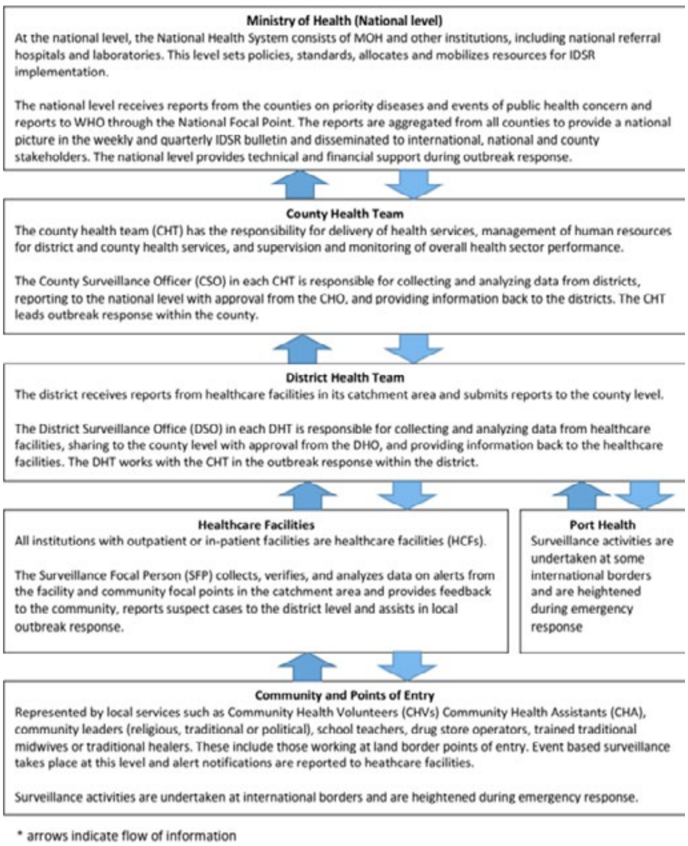

Figure 1: integrated disease surveillance and response (IDSR) flow of information at each level of Liberia's public health system

Data quality assessment (DQA) tool: the WHO DQA tool was used for the assessment. The tool was piloted in Montserrado County. Techniques used for data collection were direct observation of data collection and management at all levels. At the health facility, the source of data (patients ledgers and surveillance ledgers) were reviewed, surveillance officers at that level were observed documenting the data or information, interviews and focused group discussions with health facility surveillance focal persons, ZSOs, DSOs and CSOs were conducted by the assessment team form NPHIL/MOH/WHO/ CDC/ John Hopkins University (JHU). Surveillance staff background and training history, competency, specimen collection procedures, case reporting procedures, data analysis,

Table 1: data quality assessment (DQA) activities implementation schedule, 2017

Phase 1: preparation	**January 2-March 14, 2017**
	Identifying resources, partners, and staff, scheduling activities, venues, and transport, finalizing protocol and data collection tools (printed or electronic). An estimated budget should be developed along with a timeline and agenda of planned activities.
Phase 2: desk Review	**January 16-20, 2017**
	Review IDSR surveillance information flow by developing a data flow schematic. Review IDSR surveillance data disaggregated by sub-national levels Select Field Assessment sites. **Timeline: 1 week**
Phase 3: field assessment	**March 13-April 1, 2017**
Includes planning	**Identify Teams** A 3-day training on assessment protocol and piloting of questionnaires. Conduct assessment and summarize findings. **Timeline: 14 days**
Phase 4: develop an action plan	**April 3-4, 2017**
	Develop an action plan for next steps to address challenges, weaknesses, and improvements. Use assessment finding to inform supportive supervision plan. **Timeline: 2 days**
Phase 5: Report writing	Analyze data. Develop draft report for inputs from staff and partners. **Timeline: 8 (working) days**
	April 17, 2017
Result dissemination	Presentation of results/findings. **Timeline: 1 day**

interpretation, and use, support Infrastructure, data Sources, validation of maternal deaths, acute bloody diarrhea, measles, and acute flaccid paralysis, IDSR weekly reporting form, health management information system, health facility registers & charts, identification of key areas for improvement, action items, supervision, mentorship, and feedback and perceptions, knowledge, and attitudes about surveillance.

Key informants: these were the surveillance focal persons, district surveillance officers and County ourveillance officers. An interviewer-administered questionnaire was used to interview key informants to assess their knowledge on data quality and operations of the surveillance system. The field assessment was carried out by five (5) teams comprising of four (4) persons. One team was assigned to each county. Each team was made up of a NPHIL staff (National level), a surveillance officer (County level) and a staff from supporting agencies such as WHO, CDC and JHU. Permission was sought from the MoH and NPHIL to carry out this study as part of strengthening public health surveillance in Liberia. Verbal or written consent was obtained from all interviewees and confidentiality was guaranteed, and the questionnaire for this data quality assessment was structured according to the levels of Liberia health care delivery system (Figure 2).

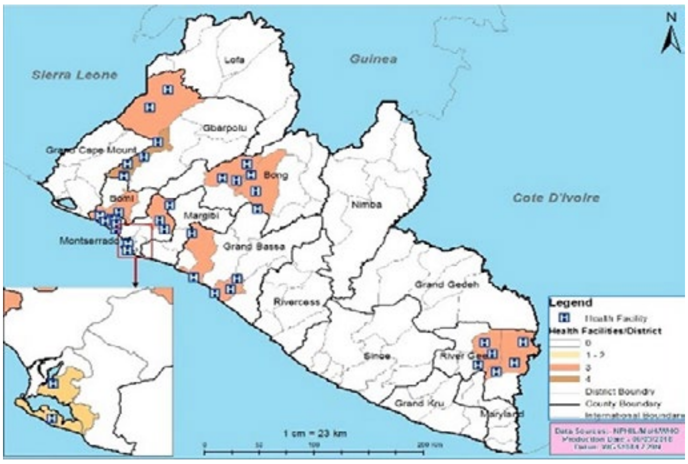

Figure 2: graphical distribution of study facilities, Liberia, 2017

Data quality audit process: as part of the monitoring and evaluation strategies for continuous improvement in surveillance activities, a data quality audit (DQA) was conducted in five selected counties to assess the quality of data generated and determine factors that influence the quality of surveillance data within the IDSR reporting system. A descriptive cross-sectional study was conducted in 30 health facilities A multi-stage cluster sampling technique was used. Five counties (Montserrado, River Gee, Bong, Grand Bassa, and Gbarpolu), were initially selected using simple random sampling. The districts under each county were classified as urban and rural. In each stratum, one health district was selected giving a total of ten (10) health districts. Within each health district three (3) health facilities were randomly sampled making a total of 30 health facilities (Figure 3).

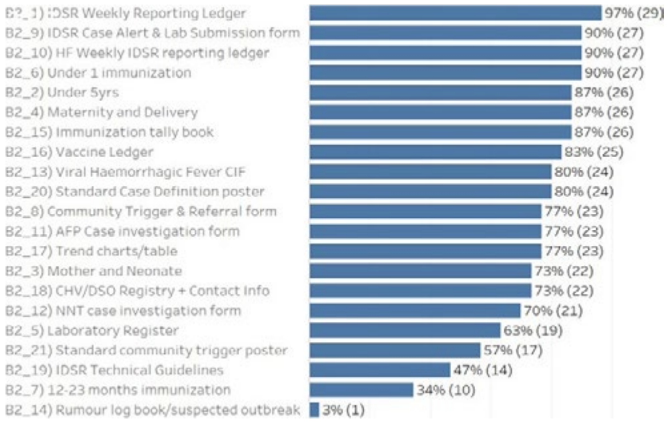

Figure 3: data sources at health facilities, data quality audit, 2017

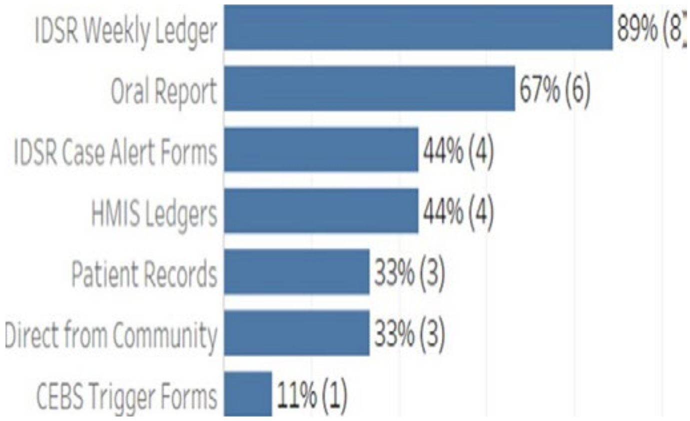

Figure 5: display of data in health facility for IDSR implementing, Liberia, 2017

Results

The findings indicated that 23% (7/29) reported a dedicated phone for the health facility, 20% (6/29) reported no cell phone network, 17% (5/29) reported daily access to internet, 56.6% (17/29) reported a consistent supply of electricity, no facility reported access to functional laptop and 70% (21/29) reported access to a motorbike for community visits (Figure 4). The findings also indicated that all the DSOs correctly recalled the definition of zero reporting, case definition for measles, and case definition for maternal death. Only one DSO did not correctly recall epidemiology week, and AFP case. Recall of diseases under surveillance was >80% for all conditions (Figure 5). During the data quality audit, it was observed that 40% of health facilities have experienced a stock out of lab packaging supplies in the past year; Stock outs lasted an average of 2 months; All types of packaging was reported as low stock, including red top tubes, purple top tubes; About half of the surveyed health facilities delivered specimens through Riders, about half were assisted by the DSO while there was a large variety in the reported packaging process, with many staff unable to give clear processes. The findings during the exercise indicated that 91% of health facility staff were mentored on data quality check and data management including the importance of the timeliness and completeness of reporting through supportive supervision and mentorship; 65% of the health facility assessed received supervision on IDSR Core Performance Indicator; and 58% of the health facility Officer In Charge gave feedback to the community level. It also indicated that, 78% of the health facility use Bar chart as methods to detect outbreaks; 56% used trend lines; 33% used summary table and 11% used map to determine outbreaks. The findings further indicated that for routine data harmonization at the peripheral level of the IDSR implementation, 90% of the DSOs routinely check the DHIS2 platform for data consistency with IDSR data reported the same period; it was also observed that 40% of the health facility focal persons lack training in data management; while 85% of the health facility recorded information on cases detected at community level.

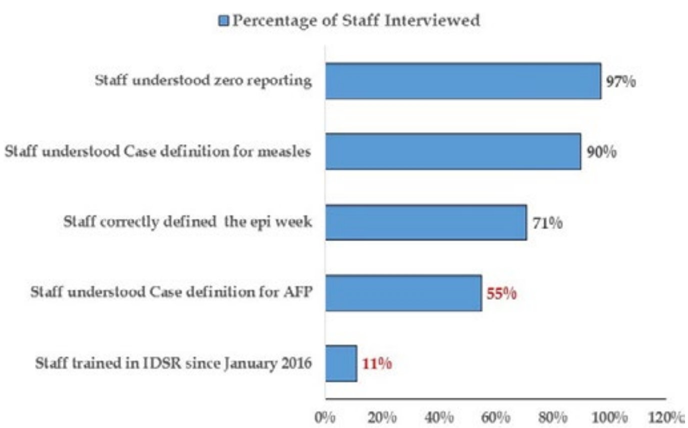

Figure 4: district level staff, data quality audit, Liberia, 2017

For the data analysis and use: a checklist as per WHO guidelines for data quality audit was used to assess key indicators of quality surveillance data. A vicariate and bivariate analysis was conducted to summarize data collected using Epi Inform™ version Most health facilities reported using data to inform topics during the health talks. 100% of the DSOs assessed, correctly recalled the definition of zero reporting, case definition for measles, and case definition for maternal death and high numbers of disease are used for sensitization, specifically around measles and diarrhea 1 DSO did not correctly recall the epidemiologic week, and AFP case. Recall of diseases under surveillance was >80% for all conditions.

Discussion

Sound and reliable data quality assessment is vital to obtain the high data quality which enhances users' confidence in public health and their performance. As Liberia monitors and evaluates the performance and progress of IDSR indicators, the need for data quality assessment in public health information system that store the performance-and-progress-related data needs to be routinely undertaken to ensure generation of credible, reliable and quality data. High quality data and effective data quality assessment are required for accurately evaluating the impact of public health interventions and measuring public health outcomes. Data use, and data collection process as the major dimensions of data quality, all need to be continuously assessed for overall data quality. Data quality audit "DQA" has been routinely conducted by MoH/NPHIL-Liberia as part of the IDSR implementation strategy to improve disease surveillance and the information generated helps to improve training, supervision, and reporting tools of the program across the country. Data are essential to public health. They represent and reflect public health practice. The broad application of data in IDSR for the evaluation of public health accountability and performance has raised the awareness of NPHIL, MoH, WHO and public health agencies of data quality, and of methods and approaches for its assessment [13].

We systematically reviewed the current status of quality assessment for each of the three dimensions of data quality: data, data collection process and data use. The results suggest existence of data capture tools at all levels of health care system with most assessed indicators above 80%. Our findings based on the proposed conceptual framework of data quality assessment for public health identified gaps in reporting aggregated IDSR data not harmonised with DHIS2, and limited data use for decision making. Data quality is influenced by technical, organizational, behavioural and environmental factors. It covers large information systems contexts, specific knowledge and multi-disciplinary techniques. Data quality audit is frequently done as a component of the quality or effectiveness or performance of the IDSR. However, data quality assessment hidden within other scopes may lead to ignorance of data management and thereby the unawareness of data quality problems enduring in public health practice. Data quality needs to be positioned at the forefront of IDSR as a distinct area that deserves specific scientific research and management investment [14].

While this review provides a detailed overview of data quality assessment issues, there are some limitations in its coverage, constrained by the access to the databases and the breadth of public health information systems making it challenging to conduct systematic comparison among studies. The importance of systematic, scientific data quality assessment needs to be highlighted. All three dimensions of data quality, data use and data collection process, need to be systematically evaluated. The quality of data use and data collection process has not received adequate attention. This lack of recognition of data use and data collection process might reflect a lack of consensus on the dimensions of data quality. Further development in methods to assess data collection process and data use is required. Effort should also be directed towards clear conceptualisation of the definitions of the relevant terms that are commonly used to describe and measure data quality, such as the dimensions and attributes of data quality. Data quality assessment was mixed methods (qualitative and quantitative assessment methods) to assess data from multiple sources (records, organisational documentation, and data collection process and data users) and used at health facility, district and county levels. The validity of a study would be doubtful if the quality of data could not be verified in the field, especially when the data from data capture tools are varied with data submitted to national level has no errors. This was limited by the coverage to 5 out of 15 counties and to the databases of IDSR, DHIS2 and data capture tools at health facility, district and county levels. Further research could develop consistent data quality definitions, attributes, quality of data use and the quality of data collection process. Data-use and data-process have not been given adequate attention at health facility, district and county levels, although they were equally important factors which determine the quality of data.

Recommendations: conduct regular data harmonization/audit at subnational level to ensure that health workers are knowledgeable on the importance of quality and reliable data. Capacity building for health workers at sub national level in data management. Ensure the institutionalize data management training in pre-service and academic institutions, on-going in-service refresher trainings in data analysis for public health actions. Establish an effective system to improve data harmonization at the subnational level.

Conclusion

Public health is a data-intensive field which needs high-quality data and authoritative information to support public health assessment, decision-making and to assure the health of communities. Data quality assessment is important for public health. In this review Completeness, accuracy, and timeliness were the three most-assessed attributes. Quantitative data quality assessment primarily used descriptive surveys and data audits, while qualitative data quality assessment methods include primarily interview, questionnaire administration, documentation review and field observation. We found that data-use and data-process have not been given adequate attention, although they were equally important factors which determine the quality of data. Other limitations of the previous studies were inconsistency in the definition of the attributes of data quality, failure to address data users' concerns and a lack of triangulation of mixed methods for data quality assessment. The reliability and validity of the data quality assessment were rarely reported. These gaps suggest that in the future, data quality assessment for public health needs to consider equally the three dimensions of data quality, data, data use and data process. Measuring the perceptions of end users or consumers towards data quality will enrich our understanding of data quality issues Data use is limited to risk communication and sensitization, no examples of use of data for prioritization or decision making.

What is known about this topic

- Data quality audits lead to improvement in over reporting and under reporting which compromise informed decisions, integrity of generated data, quality assurance standards and compliance levels;
- Public health is a data-intensive field which requires high-quality data to support public health decision-making;
- Improving data quality requires good data capturing tools that are capable of analysing the quality of data generated based on data quality audits.

What this study adds

- Forty percent (40%) of surveillance officers at health facility level lack training in data management;
- Undefined data management strategy and quality level makes data generated overwhelming and less useful in decision making;
- Regular data quality audit is necessary to understand the actual status of data quality and integrity issues in the health care delivery system and addresses data quality challenges aimed at improving data consistency, reliability and informed decisions.

Competing interests

The authors declare no competing interest.

Authors' contributions

Thomas Nagbe, Kwuakuan Yealue, Joseph Asamoah Frimpong, led the development of the conceptual framework of the manuscript, collected the data, performed the data analysis and interpretation, drafted and coordinated manuscript writing and wrote the first draft, all others participated in data collection. Monday Julius Rude, reorganized the first draft critically for key logical content. Roland Tuopileyi, Laura Skrip, Nuha Mouhamoud, Monday Julius Rude, Trokon Yeabah: data collection, data analysis and read critically the manuscript, provided the necessary corrections and approved for submission. Mary Stephen, Okeibunor Joseph Chukwudi, Ambrose Talisuna, Chukwuemeka Agbo, Ali Ahmed Yahaya: data collection, data analysis, read critically reviewed, corrected and approved the manuscript Alex Gasasira, Thomas Nagbe, Ibrahima Socé Fall, Soatiana Rajatonirina, Esther Hamblion, Chukwuemeka Agbo and Bernice Dahn read critically the manuscript and provided corrections, inputs and were involved in data analysis. All authors read and approved the final version of the manuscript and agreed upon submission for publication.

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