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The public health situation in South Sudan, a humanitarian context: successes, challenges and key lessons for the future

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

The revitalized peace agreement in South Sudan, the World's youngest nation, provides a new impetus for rebuilding the country. Thus, there is a need for concerted efforts to strengthen the health system's resilience towards attaining Universal Health Coverage (UHC) for the people of the country. In this regard, this special supplement highlights the successes and challenges of implementing key public health interventions in the country. The articles provide evidence for the rapid implementation of key recommendations aimed at attaining UHC in the country. The supplement is a collaboration between the Ministry of Health and the World Health Organization, South Sudan.

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Editorial

South Sudan's road to universal health coverage: a slow but steady journey

Victoria Achut Anib[1], Mayen Machut Achiek[1], Fabian Ndenzako[2], Olushayo Oluseun Olu[2,&]

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Abstract

Amidst the myriad of challenges that constrain good quality health care services delivery in the World's youngest nation, South Sudan, there is a beacon of hope. The country's revitalized peace agreement offers a new impetus for rebuilding the country, including its health system. Key achievements in the health care sector of the country such as development and implementation of a health sector strategic and health sector stabilization and recovery plans and implementation of a Boma Health Initiative programme which aims to scale up health services delivery at the community level provide a foundation on which acceleration of universal health coverage could rest. Other key achievements include polio-free certification of the country, significant reductions in the prevalence of Guinea Worm and other neglected tropical diseases and timely detection and response to the ongoing COVID-19 outbreak. Moving forward, attainment of universal health coverage in the country requires a strong and people-centred primary healthcare approach which will ensure that services reach the last mile. Bridging the humanitarian-development nexus is required to ensure accelerated recovery of the country's health system. Furthermore, scaling up of community-based health initiatives such as the Boma Health Initiative as platforms for taking good quality health services to the hard-to-reach areas is imperative. This Journal Supplement highlights the key achievements and challenges on the road to universal health coverage in South Sudan and provides evidence-based information for rapidly scaling up health services provision.

Editorial

Universal Health Coverage (UHC), a flagship target of the third Sustainable Development Goal (SDG3), is a situation where all persons have access to the required quality health services as at when and where they need them without having to encounter any financial barrier in doing so [1]. Three key elements are paramount for the attainment of UHC, namely availability of essential health services, including health promotion, curative and preventive services, good quality of and financial access to the health services [1]. South Sudan, the youngest nation globally, does not meet any of the three key elements of UHC. Inheriting a rudimentary health system at independence in 2011, the country has struggled to provide access to good quality health services to its people [2]. This is due to a major dearth of health care workers, non-functional supply chain management system for essential medicines and medical supplies, weak health coordination and oversight system which limits access to basic healthcare services [3]. Furthermore, the less than 3% of its GDP which is allocated to the health sector and out of pocket spending on health of over 50% is inadequate to fund healthcare services delivery in the country [4]. Thus, most of the available health care services are primarily provided by national and international non-governmental organizations (NGOs) which are largely funded externally [5].

The civil conflicts of 2013/14 and 2016 added further stress to an already fragmented health system resulting in further decimation of the healthcare system and erosion of the progress made in the first two years of independence and further limiting the country´s capacity to deliver good quality services [5]. The country´s public health indicators remain one of the lowest globally. As of 2017, access to healthcare services was 28% [2]. Immunization coverage is less than 50%, while life expectancy at birth, maternal mortality ratio and under-five mortality are respectively 58 years, 789 per 100,000 live births and 92.6 per 1000 live births [6,7]. Other factors outside the health system such as weak transport infrastructure, climatic conditions and insecurity due to recurrent inter-communal clashes that render more than half the country physically inaccessible by land for several months of the year further compound the country´s inability to achieve UHC.

However, there is a ray of hope in the country´s health sector even in the face of this grim situation. The revitalized peace agreement has brought a new impetus for rebuilding the country, including its health system. A health sector strategic plan (HSSP) has been developed and is being implemented, albeit slowly. In 2019, health partners supported the Ministry of Health in developing and implementing a health sector stabilization and recovery plan that aims to strengthen the health system resilience through accelerated implementation of the HSSP. A Boma Health Initiative (BHI) programme which aims to scale up health services delivery at the community level has been launched with support from partners [8]. The production, absorption and retention of various cadres of human resources for health are being accelerated. In addition, several strategic documents such as the health financing strategy, basic package of health and nutrition services and national health accounts have been developed and implemented to support the attainment of UHC and health-related SDGs [9].

Following an intensive childhood immunization programme using routine and supplementary strategies, the country and four other African countries were certified wild poliovirus free in 2020 [10]. Significant reductions have also been achieved in the prevalence of Guinea Worm and other neglected tropical diseases [11]. Several public health surveys which generated baseline data for evidence-based planning, implementation, supervision, monitoring and evaluation of essential health services have been conducted [12]. A national action plan for health security, including an effective disease surveillance system that provides timely detection and response to all disease outbreaks, has also been developed and implemented [13]. This enabled the country to prevent cross border transmission of the Ebola virus disease (EVD) in the Democratic Republic of Congo [14] and timely detect and respond to the Corona Virus Disease (2019) (COVID-19) outbreak in April 2020 [15].

Way forward: strategies to fast-track South Sudan´s journey towards UHC: moving forward, the country needs to sustain these modest achievements and use them as opportunities to build the foundation for UHC attainment for its people. This requires a strong and people-centred primary health care approach that will ensure that services reach the last mile. Several strategies are required in this regard. First, the humanitarian-development nexus should be bridged by ensuring that ongoing humanitarian response lay a foundation for longer-term health system strengthening and resilience building and vice versa. Second, using a well-coordinated approach to provide systematic stabilization and recovery of the country´s health system is required. Third, the scale-up of community-based health initiatives such as the BHI as platforms for taking health services to the last mile is imperative. Fourth, using innovative, appropriate and sustainable technologies such as digital health to accelerate health services delivery would be critical in expanding health services to hard-to-reach areas. Fifth, increased advocacy for political commitment to increase domestic funding and development of stronger partnerships among all stakeholders, especially the international organizations are required to increase the financing of the health sector. Lastly, strengthened capacity for health stewardship, coordination and evidence-based strategic planning and efficient allocation and use of resources is critical.

The public health articles in this journal supplement provide evidence for rapid implementation of the foregoing recommendations. The successes, challenges and recommendations for advancing the public health agenda in the country in thematic areas such as health emergency preparedness and response, immunization including polio eradication, prevention and control of neglected tropical diseases are presented and discussed. For instance, the lessons learnt from the successful implementation of essential health programmes such as the polio eradication initiative which are presented could be used to guide stabilization and recovery of the country´s health system towards achieving UHC.

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Competing interests

The authors declare no competing interests.

Authors' contributions

The first draft of the editorial was conceptualized and written by OOO. All authors read and provided inputs into all drafts of the manuscript, agreed to be accountable for all aspects of the work and approved the final draft of the editorial for publication.

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The authors alone are responsible for the views expressed in this article, which do not necessarily represent the views, decisions, or policies of the institutions with which they are affiliated.

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Research

Prevalence and factors associated with transmission of schistosomiasis in school-aged children in South Sudan: a cross-sectional study

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Abstract

Introduction: South Sudan is affected by a high burden of Neglected Tropical Diseases (NTDs). The country is very vulnerable to NTDs due to its favourable tropical climate and multiple risk factors. However, the distribution of the diseases and the populations at risk for the various NTDs is unknown. This paper described the distribution of schistosomiasis in 58 counties and 261 schools in South Sudan.

Methods: a descriptive quantitative cross-sectional study of schistosomiasis in 58 counties in 8 states of South Sudan recruited school-aged children. Using different laboratory techniques, the children were tested for Schistosoma mansoni (*S. mansoni*) and Schistosoma haematobium (*S. haematobium*). A quantitative descriptive statistical was performed to determine the prevalence rates and the endemicity of schistosomiasis among 13,286 school-aged children.

Results: the overall prevalence of *S. mansoni* and *S. haematobium* were 6.1% and 3.7% using Kato Katz and urine filtration concentration testing techniques. The highest state prevalence was reported in Western Equatoria for both *S. mansoni* (14.7%) and *S. haematobium* (7.3%). The age of the participants varied from 4 to 18 years; of these, children 10 to 12 years old had the highest prevalence of *S. mansoni* (6.8%) and *S. haematobium* (3.7%). The prevalence of *S. mansoni* (7% male vs 5% female) and *S. haematobium* (3.6% male vs 3.1% female) were higher in males than females. The likelihood of the prevalence of *S. mansoni* in males was 1.42 (95% CI:1.23, 1.64) higher than in females, while for *S. haematobium*, 1.36 (95% CI:1.12, 1.65) higher than in females. The prevalence of *S. mansoni* and *S. haematobium* showed a statistically significant gender difference ($P < 0.05$).

Conclusion: the study had provided evidence of the distribution of schistosomiasis in South Sudan for policy direction and recommended annual preventive chemotherapy with praziquantel in all endemic areas.

Introduction

Schistosomiasis, bilharzia, or snail fever is a common neglected tropical disease (NTD), highly endemic in the tropics and subtropical areas [1]. It is caused by trematode parasites of the genus Schistosoma which has five species known to infect and cause morbidity in humans, namely *S. haematobium*, S. intercalatum, S. japonicum, S. mekongi, and *S. mansoni* [2]. Sexual reproduction occurs in the human host, where fertilized eggs are produced and released through urine and stool. The eggs trapped in tissues induce inflammation and die [3]. In freshwater, free-living miracidia released by the eggs infect the snail and undergo asexual replication to release the cercariae, which penetrates the skin of humans who come into contact with the infested water [2]. The African region is predominantly affected by *S. mansoni* and *S. haematobium* due to the availability of freshwater where the intermediate hosts thrive well. S. japonicum and S. mekongi are confined to Asia, while the Caribbean and Latin America are affected mainly by *S. mansoni* [4]. Schistosomiasis is the commonest NTD affecting at least 230 million people globally. Sub-Saharan Africa contributes 90% of the disease burden [1-3].

Acute schistosomiasis, or "Katayama Syndrome" is a short-lived hypersensitivity reaction related to tissue migration of the larva. Acute infection presents as fever, myalgia, headache, cough, and rash. The symptoms appear 14-84 days after infection and may last for several weeks [5]. At the same time, chronic diseases include bladder cancer, blood in the stool, constipation, diarrhoea, bowel wall ulceration, fibrosis, hyperplasia, polyposis, and portal hypertension [5,6].

In South Sudan, hospital records have indicated ongoing schistosomiasis transmission in Upper Nile, Jonglei, Eastern and Central Equatoria states with two species, *S. mansoni* and *S. haematobium*. The eastern and central parts of South Sudan including Jongile, Unity, Upper Nile state, and Greater Pibor Administrative Area (GPAA) is prone to frequent flooding. Abnormally heavy rainfall causes the overflow of Lol, Nile, Pibor, Sobat and other rivers that lead to inland flooding where people reside and causes displacement. In addition, the flooding increases the chance of contact between people and the parasite carrying an intermediate host [7,8]. A survey conducted in 2009 in Northern Bahr el Ghazal showed that *S. haematobium* is endemic mainly in areas along the Lol River [9]. In a 2010 survey, both *S. mansoni* and S.haematobium were endemic throughout Unity and some foci in Central Equatoria and Eastern Equatoria States [10]. These observations suggested that schistosomiasis was present, and transmission was ongoing; however, the country's actual geographical distribution, extent, and prevalence remain unknown. South Sudan is yet to scale up and sustain control activities, ensure access to essential medicines, and complement public health interventions in response to the resolution of World Health Assembly 54 (WHA54) schistosomiasis and soil-transmitted helminth infections [11]. To adequately implement control and elimination measures, and monitor and assess the impact of interventions, accurate estimates of the disease burden and prevalence are crucial. The manuscript describes the national distribution of human schistosomiasis in 58 counties from 2016 through 2019.

Methods

Study design and area: we conducted a cross-sectional quantitative study to know the prevalence of schistosomiasis among school-aged children 10 to 14 years of age in South Sudan from 2016 to 2019. The study was based on the methods and procedures stated recommendation under WHO neglected tropical diseases transmission assessment survey guidelines [12].

Study site selection and sample size: South Sudan is administratively divided into 10 states which are further divided into 79 counties. Twenty-two counties in four states, with available recent schistosomiasis prevalence data, were identified and excluded from the current study. The states without prevalence and transmission risk data were included in the study. Besides, the selection was guided by previous knowledge of ecological factors (i.e., proximity to lakes, streams, and other water bodies) from different geographical locations [13]. It had helped the management of survey implementation including logistics constraints. All 52 counties in the six remaining states and six counties (Panyijar county from Unity and Kapoeta South, Kapoeta North, Torit, Magwi, and Lapon counties from Eastern Equatoria) were included in the study with a total of 58 counties. In these counties, the selection of schools was based on the WHO survey sample builder stated in the assessment guideline [12]. It is an excel based tool used to develop survey design and random samples. It had facilitated the random selection of schools and children from a list of randomized numbers. A cluster-based simple random sampling technique was applied to select five schools in each county. Before the section of the schools, all schools in the county were listed down for random sections. Fifty children aged between 10 and 14 years, balanced by gender, from each school were randomly enrolled on the study. WHO NTD transmission assessment survey guideline recommends 50 children per cluster [12]. When the target was not reached, children from an expanded age range were selected. Otherwise, the target age from the surrounding villages or the nearest school was sampled to complete the required samples. Each child submitted a stool and urine sample to test the presence of intestinal Schistosoma (*S. mansoni*) eggs and urinary Schistosoma (*S. haematobium*), respectively.

Data collection: the data collection was conducted by nine teams, each comprising a supervisor (i.e. laboratory technologist or an experienced laboratory technician), two laboratory technicians, a data clerk and a social mobilizer. A data manager coordinated the work of all data clerks and had access to the Open Data Kit (ODK) web-based cloud to monitor data as entries were made and uploaded using smartphones. A detailed fieldwork plan was developed based on the teams created and the counties included in the study. The local health personnel led the study teams to the selected schools. Geographical coordinates (i.e. longitude, latitude, and altitude) were taken at the survey sites using smartphones. Children aged between 10 to 14 years were randomly selected, and both urine and stool samples were collected from the selected children. The survey determined the prevalence of *S. haematobium* based on micro-hematuria or parasite eggs in urine using reagent dipstick and urine filtration procedures, respectively. A reagent dipstick for hematuria is a qualitative rapid diagnostic tool used to screen school-aged children for urinary schistosomiasis. The interpretation of the result was based on the presence or absence of a test strip line. Samples with red test lines were labelled as positive; however, further quantification of the test line was not performed. The urine filtration procedures determine the concentration of the egg per 10 millilitres (ml) of the urine sample. The testing result was reported as light: <50 ova per 10ml; heavy: ≥50 ova per 10ml.

The prevalence of *S. mansoni* was determined parasite eggs in stool using Kato Katz or circulating cathodic antigen (CCA) in urine. The Kato Katz technique is used for semi-quantitative and quantitative diagnosis of Schistosoma species (*S. mansoni*), soil-transmitted helminthiasis caused by Trichuris trichiura, hookworm, and ascaris lumbricoides. WHO had recommended the use of the technique in areas with moderate to high transmission of intestinal schistosomiasis (10-49.9% and ≥50%) [14]. A gram of faeces was collected and tested for the presence of an egg (egg per gram of faeces) using a microscope. The testing result was reported as light infection (0-99 e.p.g.), medium (100-399 e.p.g.), and heavy: (≥400 e.p.g.). A point-of-care Circulating Cathodic Antigen (POC-CCA) urine test is a simplified rapid diagnostic test (RDT) used for the qualitative detection of an active *S. mansoni* infection. The test detects Schistosoma specific antigen execrated in urine [15]. The result was labelled positive based on the appearance of a visible test line seen within 20 minutes of application of the urine. The prevalence estimate for each survey site was classified into non-endemic (0%), low (<10%), moderate (10-49.9%), or high-risk (≥50%). The prevalence estimate for each survey site was classified into non-endemic (0%), low (<10%), moderate (10-49.9%), or high-risk (≥50%) areas.

Data analyses: in 2016, data were captured on to a server hosted at the national level using Bold Like Us (BLU) Studio 5.5 smartphones running Android 4.2 (Jelly Bean) through a modified version of Open Data Kit (ODK), the LINKS application. Raw data on schistosoma infection were downloaded into Microsoft Excel, cleaned, and summarized from the server. In subsequent years, the Expanded Special Project for Elimination of Neglected Tropical Diseases (ESPEN) Collect application was used to capture, facilitate cleaning, and aggregation collected individual data into site data. The data entered was synchronized and hosted at the Standard Code Server. Only authorized officers had access to download individual data from the dashboard on the server. We conducted descriptive analyses on socio-demographic characteristics and epidemiological distribution of schistosomiasis. We have used International Business Machine (IBM) Statistical Package for Social Science Window Version 26.0 (SPSS V26) to conduct descriptive epidemiology. A prevalence map was produced using ArcGIS (ESRI, California, and the USA). A two-by-two table was used to determine the relationship between test types (urine filtration versus dipstick and CCA versus Kato Katz) and test result (positive versus negative). A two-by-two table was performed to compare whether the observed prevalence of *S. haematobium* and *S. mansoni* results for the two test types for each species were statistically different enough to reject the null hypothesis (there is no significant difference between the two test types) at a 95% confidence interval (CI) and a significant level of 0.05.

Ethical consideration: during the 2016, 2018, 2019 survey ethical approval was obtained from the Research and Ethics Committee of the national Ministry of Health. During the survey, consent was obtained from the headteachers and parents. All positive cases found during the study received a single dose of 20 mg/kg praziquantel. However, ethical approval was not obtained to use the secondary anonymized data in the analysis. Data protection measures were employed to ensure the security of the data.

Table 1: socio-demographic characteristics of schistosomiasis in school-aged children, South Sudan (2016 to 2019)

Variables	Category	Number tested (N)	*S. mansoni*		*S. haematobium*		Co-infection	
			Tested positive	Prevalence (%)	Tested positive	Prevalence (%)	Tested positive	Prevalence (%)
State	Eastern Equatoria	1130	23	2	3	0.3	0	0
	Jonglei	2833	331	11.7	172	6.1	102	3.6
	Lakes	1822	94	5.2	3	0.2	0	0
	Unity	99	2	2	17	17.2	0	0
	Upper Nile	2764	11	0.4	92	3.3	7	0.3
	Warrap	1606	4	0.2	31	1.9	0	0
	Western Bar el Ghazal	745	2	0.3	2	0.3	2	0.3
	Western Equatoria	2287	337	14.7	167	7.3	114	5
Gender	Male	6982	488	7.0	248	3.6	125	1.9
	Female	6304	316	5.0	193	3.1	110	1.6
Age group	0-4	6	0	0.0	0	0/0	0	0.0
	5-9	1085	72	6.6	19	1.8	16	1.5
	10-12	7232	494	6.8	267	3.7	210	2.9
	13-15	4958	238	4.8	155	3.1	9	0.2
	>15	5	0	0.0	0	0.0	0	0.0

Note: the prevalence of S. mansoni and S. hamatobium was calculated using the stool Kato-Katz testing and urine filtration concentration respectively. The two tests were conducted in 2016, 2018 and 2019; however, circulating cathodic antigen (CCA)-(S. mansoni) and urine dipstick was only available in 2016.

Results

Study population and schistosoma infection prevalence: the screening of the 13,286 samples collected from the children revealed the presence of both *S. haematobium* (n=441) and *S. mansoni* (n=804) Table 1. The age of the children tested varied from 4 to 18 years old. The age group 10 to 12 years had the highest prevalence rate for *S. mansoni*, *S. haematobium*, and Co-infection of the two species. Of the 6,982 males tested for *S. mansoni*, 7% tested positive. The prevalence of *S. mansoni* in males was 1.42 (95% CI: 1.23,1.64) times higher than in females. Regarding *S. haematobium*, 3.8% of males were tested positive compared to 2.8% positive females. The prevalence of *S. haematobium* in males was 1.36 (95% CI:1.12,1.65) times greater than in females.

Prevalence of schistosoma infection by location: *S. mansoni* infection was found in all the eight states of South Sudan, with an overall prevalence rate of 6.1% as shown in Table 2. Western Equatoria had the highest prevalence rate of S. manosni (14.7%). The prevalence rate varied from 0 to 65.9% at the county level, with the highest in Bor South (65.9%). At the school level, 86% out of 261 schools were endemic to *S. mansoni*. The school prevalence rate of S. manosni varied from 0 to 93.3%; the highest was recorded at Bandala primary school in Nagero county (93.3%) of Western Equatoria state. *S. haematobium*, infection was found in all eight states with an overall prevalence rate of 3.7%. Unity state had the highest prevalence rate (17.2%) Table 2. At the primary school level, 72 (%) out of 261 schools were endemic to *S. haematobium*. The school prevalence rate varied from 0% to 84.4%, with the highest at Toch primary school in Old Fangak (84.4%) in Jonglei state. Overall, high endemicity for schistosomiasis combined is in Bor South, Old Fangak, Ezo and Ibba counties as indicated in Figure 1. Bor South county has highest the endemicity for *S. mansoni* species.

Prevalence of parasitic intensity: light intensity infection (1-99 egg per gram of faeces (e.p.g.) for *S. mansoni* by Kato Katz technique was observed in all the states that varied from 0.2 and 13.6% as indicated in Table 3. Western Equatoria recording the highest. Medium intensity infections (100-399 e.p.g. of faeces) were observed in five out of the eight states at 1.3% in Jonglei, 1.1% in Western Equatoria and 0.1% each in Eastern Equatoria, Lakes and Warrap states and heavy intensity infection (>400 e.p.g. of faeces) was observed in three states of Jonglei at 0.9%, Western Equatoria 0.3% and Lakes 0.1%. For *S. haematobium* using urine filtration, light intensity infection (<50 eggs/10mls of urine)

Table 2: summary of Schistosoma mansoni laboratory test, South Sudan (2016 to 2019)							
State	**Stool: Kato-Katz (*S. mansoni*)**					**Urine: circulating cathodic antigen (CCA)- (*S. mansoni*)**	
	Number of stools tested	**Prevalence rate (%)**	**Infection intensity (eggs per gram of faeces) [% of positive)**			**Number of samples tested**	**Prevalence rate (%)**
			Light	**Medium**	**Heavy**		
Eastern Equatoria	1130	2.0	1.9	0.1	0.0	1130	15.6
Jonglei	2833	11.7	9.5	1.3	0.9	840	34.0
Lakes	1822	5.2	4.9	0.1	0.1	1822	12.8
Unity	99	2.0	2.0	0.0	0.0	-	-
Upper Nile	2764	0.4	0.4	0.0	0.0	-	
Warrap	1606	0.2	0.2	0.1	0.0	1406	18.1
Western Bar el Ghazal	745	0.3	0.3	0.0	0.0	-	
Western Equatoria	2287	14.7	13.6	1.1	0.3	649	30.8
Total	13286	6.1	5.3	0.5	0.3	5847	19.7

Intensity by Kato-Katz: light: 0-99 egg per gram of faeces (e.p.g.); medium: 100-399 e.p.g.; heavy: ≥ 400 e.p.g; intensity by urine filtration: light: < 50 ova per 10 ml; heavy: ≥ 50 ova per 10 ml; point of care-Schistosoma circulating cathodic antigen (POC-CCA) was used in 2016 in five states.

Table 3: summary of Schistosoma haematobium laboratory test, South Sudan (2016 to 2019)						
State	**Urine: filtration concentration**				**Urine dipstick**	
	Number of samples tested	**Prevalence (%)]**	**Infection intensity (eggs per 10 ml) [% of positives]**		**Number of samples collected**	**Prevalence (%)**
			Light	**Heavy**		
Eastern Equatoria	1130	0.3	0.1	0.2	-	-
Jonglei	2833	6.1	3.8	2.3	1993	3.2
Lakes	1822	0.2	0.1	0.1	-	-
Unity	99	17.2	16.2	1.0	99	26.3
Upper Nile	2764	3.3	2.3	1.0	2764	3.6
Warrap	1606	1.9	0.7	1.2	200	0.0
Western Bar el Ghazal	745	0.3	0.3	0.0	745	0.3
Western Equatoria	2287	7.3	4.4	2.9	1638	3.9
Total	13286	3.7	2.3	1.4	7439	3.4

Note: Intensity by urine filtration: light: < 50 ova per 10 ml; heavy: ≥ 50 ova per 10 ml

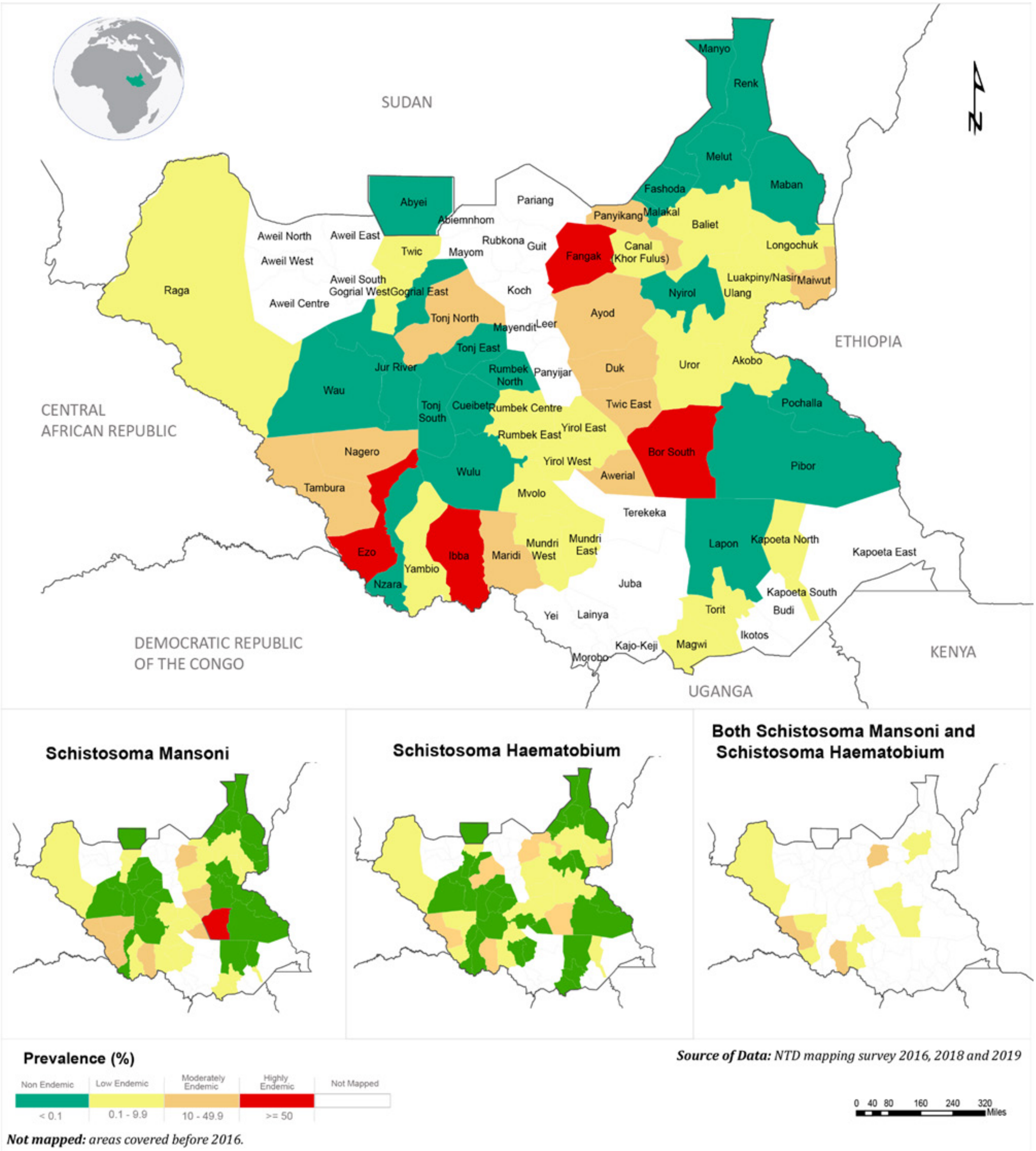

Figure 1: schistosomiasis endemicity map, South Sudan (2016 to 2019)

was observed in the eight states with the highest in Unity (16.2%), Western Equatoria (4.4%) and Jonglei (3.8%), while heavy intensity infections (>50 eggs/10mls of urine) were observed in all except Western Bahr el Ghazal.

Overall, the *S. mansoni* prevalence rate for 2016 surveys using Circulating Cathodic Antigen (CCA) was 19.7%, while for the Kato Katz technique was 7.8%. The likelihood of the test being positive was 2.87 (95% CI: 2.54, 3.24) higher for CCA than Kato Katz. There was a statistically significant difference between the two tests (P<.001) (Table 4). As for *S. haematobium*, the overall prevalence rate using urine filtration was 5.0%, while for dipstick was 3.4%. The likelihood of the test being positive was 1.49 (95% CI: 1.27, 1.75) higher in urine filtration compared to the dipstick. There was a statistically significant difference between the two tests (P<.001) (Table 4).

Table 4: comparison of the performance of different tests used for *S. mansoni* and *S. haematobium* testing, South Sudan (2016 to 2019)

Test type	Positive	Negative	Total	Odds ratio	P-value	95% confidence interval
circulating cathodic antigen	1149(19.7%)	4698(80.3%)	5847 (100%)			
Kato-Katz	400(7.8%)	4698 (92.8)	5098 (100%)	2.87	<.001	(2.54, 3.24)
Total	1549(14.2%)	9396 (85.8)	10945 (100%)			
Urine filtration	375(5.0%)	7064(95.0%)	7439(100%)	1.49	<.001	(1.27, 1.75)
Urine dipstick	255(3.4%)	7184(96.6%)	7339(100%)			
Total	630(4.2%)	14248(95.8)	14878(100)			

Discussion

The cross-sectional study provides the baseline data on schistosomiasis prevalence as the first sizeable school-based survey in the 58 unmapped counties of South Sudan. Our study revealed the presence of schistosomiasis infections in all the states and almost in every county with a heterogeneous prevalence rate of *S. haematobium* and *S. mansoni* across the country, indicating the latter to be highly endemic [16]. There is a high prevalence of *S. mansoni* in Jonglei, Western Equatoria and the Lakes States and *S. haematobium* in Jonglei, Unity and Western Equatoria States. Higher co-infection has been observed in Jonglei State. The parasitic intensity was light across the eight states, with heavy intensities observed more for *S. haematobium* than *S. mansoni*. Jonglei and the Western Equatoria States had co-infection of the two Schistosoma parasites [16]. Our findings showed the schistosomiasis burden in the central and southwestern regions of the country is high. The persistence of schistosomiasis's high prevalence rate over the years indicates that no control or elimination measures are being implemented [16]. In Africa, the prevalence of human schistosomiasis is dependent on the level of environmental sanitation, the suitability of the area for the intermediate snail hosts, and the type of the snails. In South Sudan, this has been exacerbated by political conflict negatively impacting the country's socio-economic status and funding for preventing and controlling infectious diseases such as schistosomiasis [17]. Previous surveys of 2010 showed a constantly lower prevalence of *S. haematobium* than that of *S. mansoni*, a similar finding in six of the eight states of our study a common feature in Madagascar due to the Biomphalaria snails in the Nile River and high positivity of *S. mansoni* [18]. One unexpected finding was the low prevalence of schistosomiasis in Eastern Equatoria (2.3%) compared to the previous survey findings of 14.2% 6 years prior. The conflicts in the region and mainly children (62% of children became refugees) and women fleeing insecurity, violence, and famine to Uganda, may elucidate the reduction [19,20]. Nonetheless, the rapid decline in prevalence rate requires further research to verify these findings and assess the contributing factors at length.

Previous schistosomiasis predictive maps for South Sudan suggested a high prevalence rate of *S. haematobium* in Greater Bahr El Ghazel between 10-25% and the Equatoria States at ≤5%, and findings of a non-endemic Western Bahr El Ghazal and low prevalence rate of 0.5% in Western Equatoria [21]. While the surveys of 2009 found a prevalence rate of 3% in Northern Bahr El Ghazal [9]. Deganello in 2007 reported the presence of *S. mansoni* mainly in Central Equatoria, with a national prevalence of both species between 10-25% again. This is inconsistent with our observed findings which are relatively lower with an overall prevalence rate of 7.9% (7.3-8.3% at 95% confidence interval) [22]. However, the conclusions of Jonglei were consistent with the predicted low prevalence of <5%. Overall, the current state-level data indicates an uneven distribution throughout the country, with a few previously thought-to-be highly endemic places found to be lowly or non-endemic. The prevalence of schistosomiasis from the initial prevalence rate surveys and our study is not surprising as no sustainable control measures were instituted.

An alarmingly (very high) prevalence rate of schistosomiasis was observed in Bor South, where schools recorded over 90% site prevalence rates. This high prevalence could be attributed to the long-running civil war that has devastated social and health services in the area and the presence of the schistosoma, intermediate host, and freshwater bodies. The high prevalence was seen in Bor South, Ibba, Ezo, Awerial, Nagero, and Old Fangak were comparable to other focal prevalence rate surveys in East African countries, Madagascar, Egypt, and the Democratic Republic of Congo, an indication of the high burden of schistosomiasis in South Sudan and many parts of the Africa Region [21,22]. Also, the observed high prevalence in rural areas compared to urban areas such as Wau may be attributed to inadequate sanitary facilities, contaminated water sources for domestic chores, bathing, and insufficient health education on the affected communities´ preventive measures. In some countries, urban infection is found in individuals due to urbanisation. This could be the assumption for the situation seen in Juba, the capital city of South Sudan in the state of Central Equatoria, where the prevalence is high [10]. Typically, if the intermediate host is not present in an area with schistosomiasis cases, it is easier to control through better chemotherapy, sanitation, and water access facilities [23].

Presently, chemotherapy is the most cost-effective approach to controlling schistosomiasis in the short term, but complimenting it with access to clean water and sanitation would help address the risk factors, reduce transmission, and have a broader impact on health. While the provision of water, adequate sanitation, and snail control are essential for schistosomiasis elimination, directing these interventions to selected high transmission areas would ensure a higher impact [4]. The study´s five sites per county is an innovative way to improve resource allocation for interventions to focal transmission. However, this is also a study limitation as some counties are enormous, and the five sites may not be represented precisely. The utilisation of WASH facilities through behavioural modification has been challenging in some countries despite being the best approach to managing health problems [3]. The communities require sufficient knowledge and attitude about schistosomiasis through health education in the endemic areas.

Preventive chemotherapy either school or community-based approaches have not shown significant differences in some countries following treatment [24]. Most children are exposed to similar conditions when they get home with inadequate WASH facilities. Therefore, most schistosomiasis treatment should be both community and school-based, with many children in communities. Treatment immediately after 12 months is vital because delayed repeat therapy may not suppress transmission due to persistent reinfections leading to reduced drug efficacy observed after one to three years [24]. Therefore, the state government should emphasise the need for additional non-drug control measures in highly endemic areas.

Conclusion

This study shows that schistosomiasis is endemic in South Sudan, with a moderate to high prevalence rate in most parts of the country. In these endemic communities we advise the national schistosomiasis control programme to implement the WHO recommendation of annual preventive chemotherapy with a single dose of praziquantel at 75% treatment coverage in all the age groups from 2 years. The treatment should include pregnant women in the second and third trimester, lactating women and adults. In the low endemic communities, the test and treat approach is recommended. The low parasitic intensity for both species in South Sudan is an indication that with suitable interventions, the prevalence of infection in the affected population can reduce to elimination levels. The study has generated crucial epidemiological baseline information and indicators which could guide policy formulation, monitoring, and evaluation of interventions. Heightened health education to reduce contact with contaminated water and access to safe water, sanitation, and hygiene plus environmental interventions including snail control with moluscicides should be complementary measures to reduce the prevalence and burden of schistosomiasis. The effective implementation and monitoring of these strategies will interrupt transmission and eliminate schistosomiasis in South Sudan. The verification for the interruption of transmission should use diagnostics with high sensitivity and specificity.

What is known about this topic

- Although schistosomiasis is endemic in South Sudan, the geographic distribution of the disease is unclear;

- The superior sensitivity of circulating cathodic antigen over KK in the detection of the S. mansoni circulating cathodic antigen.

What this study adds

- This study provides information on the prevalence and distribution of schistosoma infection in South Sudan;
- The younger children are at higher risk of S. mansoni infection;
- Key recommendations for scaling up effective and integrated public health measures for prevention and control of schistosomiasis including treatment of the pre-school age children.
- Malaria prevention practices are sub-optimal compared to the national targets.

Competing interests

The authors declare no competing interests.

Authors' contributions

MNS and KKB conceived and wrote the first draft of the manuscript. KKB and MNS conducted the data analyses. OOO, MNS and KKB provided insights into the study's conceptualisation and conducted an extensive review of all manuscript drafts. All authors read and provided significant inputs into all drafts of the manuscript, agreed to be accountable for all aspects of the work and approved the final draft of the manuscript for publication.

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Research

Polio eradication in a chronic conflict setting lessons from the Republic of South Sudan, 2010-2020

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Abstract

Introduction: in 1988 the World Health Assembly set an ambitious target to eradicate Wild Polio Virus (WPV) by 2000, following the successful eradication of the smallpox virus in 1980. South Sudan and the entire African region were certified WPV free on August 25, 2020. South Sudan has maintained its WPV free status since 2010, and this paper reviewed the country's progress, outlined lessons learned, and describes the remaining challenges in polio eradication.

Methods: secondary data analysis was conducted using the Ministry of Health and WHO polio surveillance datasets, routine immunisation coverage, polio campaign data, and surveys from 2010 to 2020. Relevant technical documents and reports on polio immunisation and surveillance were also reviewed. Data analysis was conducted using EPI Info 7 software.

Results: administrative routine immunisation coverage for bivalent Oral Polio Vaccine (OPV) 3rd dose declined from 77% in 2010 to 56% in 2020. In contrast, the administrative and post-campaign evaluation coverage recorded for the nationwide supplemental polio campaigns since 2011 was consistently above 85%; however, campaigns declined in number from four in 2011 to zero in 2020. Overall, 76% of notified cases of Acute Flaccid Paralysis (AFP) received three or more doses of the oral polio vaccine. The Annualized Non-AFP rate ranged between 4.0 to 5.4 per 100,000 under 15 years populations, and stool adequacy ranged from 83% to 94%.

Conclusion: South Sudan's polio-free status documentation was accepted by the ARCC in 2020, thereby enabling the African Region to be certified WPV free on August 25, 2020. However, there are concerns as the country continues to report low routine immunisation coverage and a reduction in the number of polio campaigns conducted each year. It is recommended that the country conduct high-quality nationwide supplemental polio campaigns yearly to achieve and maintain the required herd immunity. It invests in its routine immunisation program while ensuring optimal AFP surveillance performance indicators.

Introduction

Poliomyelitis is a highly infectious disease caused by polio viruses and causes irreversible paralysis in children and adults [1]. The clinical manifestation is paralysis which occurs a few hours or days after contracting the virus. However, most polio cases are asymptomatic, which helps sustain its transmission through the faecal-oral route, with communities with poor hygiene and sanitation being at high risk [2,3]. The 41st World Health Assembly (WHA) held in 1988 adopted a resolution to eradicate polio globally [4]. Subsequently, the Global Polio Eradication Initiative (GPEI), a public-private partnership, was launched and tasked with ensuring support to all countries to eradicate the disease [5-7].

The GPEI has made tremendous progress since its establishment. As of 2020, the number of paralyses caused by WPV type 1 was 140, a reduction of over 99.9% from the original 350,000 reported in 1988 before eradication efforts were implemented [8-10]. Notably, two of the three strains of WPV that cause paralysis have been eradicated, with WPV type 2 declared eradicated in September 2015 and WPV type 3 in October 2019 [11-13]. The core strategies utilised in achieving these feats are high routine immunisation coverage, provision of supplementary Oral Polio Vaccine (OPV) doses through national immunisation days, strong Acute Flaccid Paralysis (AFP) surveillance system, and "mop ups", which are targeted polio campaigns in areas of poliovirus transmission [14]. As of December 2020, all but one of the World Health Origination (WHO) regions, the Eastern Mediterranean Regions, have been certified wild poliovirus (WPV) free, with cases reported from Pakistan and Afghanistan [15,16]. The African Region was certified WPV free in August 2020 following Nigeria's eradication of WPV type 1 in 2016 [17].

South Sudan has also made tremendous progress in the eradication of polio. The last indigenous wild polio virus type 1 case was reported in 2001 in Pariang County, Unity State [18]. Though indigenous wild poliovirus was interrupted in 2001, the country experienced two imported outbreaks of WPV in 2004-2005 and 2008-2009 from Nigeria via Sudan. The country's claim of being WPV free was accepted in June 2020. However, Vaccine-Derived Polio Virus (VDPV) outbreaks continue to be recorded in the country, with the most recent outbreak declared on 18 September 2020 by the Ministry of Health (MOH) in South Sudan [19].

Polio eradication in the chronic conflict setting of South Sudan faced several challenges, including difficult access due to insecurity and terrain, disrupted health systems, destruction and looting of health facilities, and poor infrastructure. The country continues to battle with a humanitarian crisis due to the cumulative effects of years of conflict, which have destroyed people's livelihoods. As of August 2020, the humanitarian situation report noted that 7.5 million people need humanitarian assistance, with 1.6 million internally displaced and another 2.26 million living as refugees in neighboring countries [20] with a weak health system largely dependent on donors and implementing partners. Surmounting these challenges required dedicated and trained personnel with innovative strategies and approaches that are not documented in the literature. Scientific publications on the progress, challenges and lessons learned remain scarce. This paper, therefore, reports the path towards polio eradication in South Sudan and contributes to global lessons learned and best practices in the eradication initiative. Findings from the South Sudan context could be extrapolated to other countries in conflict and accelerate the global polio eradication efforts.

Methods

Study area: South Sudan is a landlocked country located in Eastern Africa. It covers approximately 640,000km2 with a projected population of 13.3 million using a 3.0% growth rate from the census figures for 2008 and a population density of 15 per square kilometre [21]. It is divided into ten states and further subdivided into 80 Counties and over 600 Payams. It attained independence on 9th July 2011, following more than two decades of civil war, with renewed civil conflicts occurring in December 2013 and again in June 2016, along with continuous fighting, which remains ongoing in the country [22]. The conflicts have spared no states or regions; however, three states, Jonglei, Unity, and Upper Nile, known as the former conflict-affected states, have felt the brunt the most and have undermined the health system's capacity to deliver essential health services. Still, despite the challenges, active surveillance of AFP cases in health facilities and communities continues facilitated by the partnership and huge polio workforce located at even the lowest level (Boma), which was well established in the country even before its independence.

Study design: we conducted a retrospective descriptive study of the polio eradication initiative in South Sudan from 2010 to 2020 through secondary analyses of quantitative data from the national polio database. Qualitative data were obtained through reviewing documents and reports on polio immunisation campaigns, AFP surveillance, and other polio eradication activities. Analysis of immunisation coverage rates included data from South Sudan District Health Information System (DHIS), WHO United Nations Children's Fund (UNICEF) Joint Reporting Form on Immunisation (JRF), and the WHO, UNICEF Immunisation Coverage Estimates (WUENIC). The polio supplemental campaign and surveillance data were obtained from the MOH and WHO databases.

Immunisation coverage and data: we used routine administrative coverage data for polio immunisation collected every month from approximately 1065 health facilities in 80 counties transmitted through the DHIS system to the national MOH database. Data on polio vaccination coverage were also retrieved from reports on the immunisation surveys and WUENIC. The polio campaign data were obtained from the tally sheets used during the campaigns and collated at all levels, with the final summary shared by states to the National level. Other data sets were analysed to determine the quality and extent of the campaign, including the post-campaign evaluations (PCEs) and lot quality assurance sampling (LQAS). Two vaccines protect against the poliovirus, the Oral Polio Vaccine (OPV) and Injectable Polio Vaccine (IPV). A child is said to be fully vaccinated against the poliovirus when OPV3 and IPV are recorded on their vaccination card. Oral polio vaccine (OPV3) is the third time a child receives an oral polio vaccine, excluding the OPV birth dose and given along with the IPV at 14 weeks or later. IPV was added to the immunisation schedule in Dec 2015. The country conducts supplementary immunisation campaigns using OPV. All children under five of age are targeted and given two drops of the polio vaccines irrespective of the child's polio vaccination status, which boosts polio herd immunity. Results are collated against set targets, with an evaluation done to determine the coverage and quality of the campaign

Acute flaccid paralysis (AFP) surveillance: the AFP surveillance system in South Sudan relies on health facilities and community-based reporting. The system detects, notifies, investigates, and verifies AFP cases in children under 15 years old or in any person a clinician suspects poliomyelitis. In South Sudan, it involves over 4500 personnel. It is a partnership between community members, Non-Government Organisations (NGOs), International Non-Government Organisations (INGOs), Civil Societies (CSO), the Rotary, and United Nations (UN) organisations led by the MOH South Sudan. There are two main AFP surveillance indicators, non-polio AFP (NP-AFP) rate, cases of acute flaccid paralysis not due to polio per 100,000 children less than 15 years with an NP-AFP rate of ≥2 agreed as the country's standard, being able to detect the poliovirus, and the stool adequacy, with 80% of the stool being adequate as the standard [23,24]. Adequate stool means that the stool must be collected within 14 days of onset of the paralysis and transported to a WHO accredited lab under a good reverse cold chain [24]. Apart from the two main polio surveillance indicators, another indicator that determines the quality of the AFP surveillance system is the non-polio enterovirus rate (NPENT). This determines the ability of the laboratory to report the poliovirus or any other virus if present in the AFP stool sample with a benchmark of 10% [25].

When a person meets the community AFP case definition, the sudden weakness of any limbs, two stool samples are collected with at least a 24-hour interval between stool collection, under the appropriate reverse cold chain. South Sudan transports all AFP samples from the states to the capital, Juba, via aeroplanes. From Juba, the AFP samples are flown to the Uganda Virus Research Institute laboratory (UVRI), a WHO accredited polio laboratory, for analysis. All AFP cases have a case-based form completed, including clinical and epidemiological information. Records are stored in a centralised MS Access Database by the WHO data manager, with a copy retained at the National Public Health Laboratory Juba. Detailed case investigation (DCI) is conducted for all reported AFP cases to authenticate if it is a true AFP case by senior WHO and MOH EPI officers. Follow-up of inadequate cases, "cases investigated after 14 days of paralysis or with inadequate samples collected," is conducted by senior officers and clinicians using detailed investigation forms entered the Open Data Kit (ODK, including its website) mobile platform and uploaded into the national database. The National Polio Expert Committee (NPEC) meets quarterly and classifies all inadequate cases while endorsing adequate cases classified by the secretariat and making applicable adjustments. Laboratory results are entered into the database for completeness as soon as received from the URVI. We analysed retrospectively the AFP database stored at the national level that was routinely collected from all states during the study period.

Review of literature: PubMed, Global Health, and Google Scholar databases were searched for original peer-reviewed articles describing polio eradication efforts in South Sudan published from 2002 to 2020. The following combinations were used as keywords to search for literature on polio: 'polio' and a combination of the following words in permutations - 'eradication + surveillance + South Sudan', 'vaccination + South Sudan'. The search yielded three articles, of which none were considered relevant because the content focused on other vaccines and not the oral or injectable polio vaccines. Additionally, all available country, regional and global reports on immunisation for the period of 2002 to 2020 was reviewed. Published and unpublished reports on AFP surveillance and immunisation data reported by the South Sudan Ministry of Health were studied, along with annual progress reports on poliomyelitis eradication activities submitted to the ARCC (2014-2020) and quarterly reports from the Polio eradication committees, which were also reviewed.

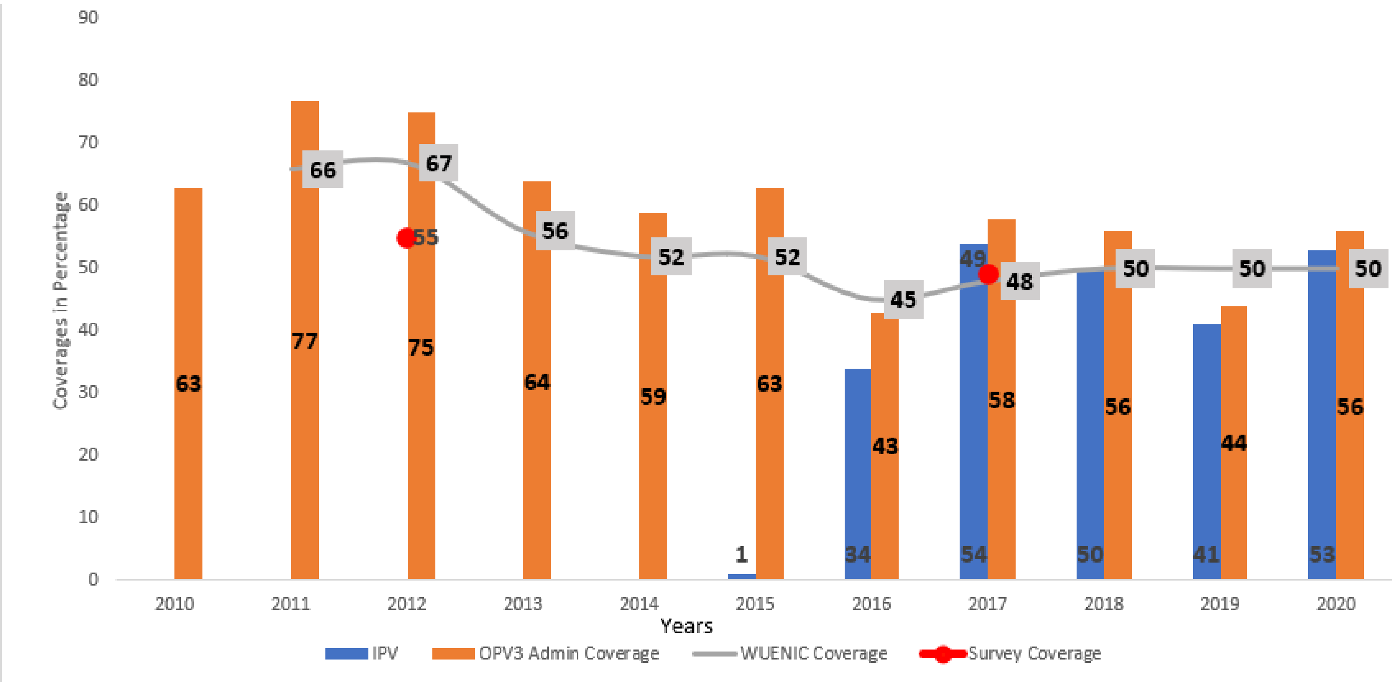
Data analysis: the database for this study was from the DHIS, a web-based open-source software platform for reporting, analysis, and dissemination of data for all health programs in the country, which was exported to MS Excel. The WHO and UNICEF for estimating global, country by country, infant immunisation coverage (WUENIC) [26], web-based, MOH campaign database, immunisation surveys, and AFP surveillance case-based database access based, all exported to Microsoft excel for validation, cleaning, and analysis. Statistical data analysis was conducted using Epi Info statistical software (version 7; CDC, Atlanta, United States). Descriptive analyses were performed to describe the epidemiology of reported AFP cases in South Sudan, and statistics based on the WHO recommended performance indicators for AFP surveillance were generated [27]. Mapping was done to visualise surveillance performance and distribution of AFP cases by location using the ArcGIS Pro software. Results of the study are presented in the form of tables and maps. Qualitative analysis for the study used reports compiled from the Annual Polio reports, the 2019-2020 Polio free documentation, and yearly GAVI Joint Appraisals and supervisory reports. These reports were reviewed, and a strengths, weaknesses, opportunities, and threats (SWOT) analysis of the polio programme was developed based on methods from Wijingaarden [28].

Ethical approval and consent: the Ministry of Health approved this study. We used secondary data collected and stored at WCO and MOH. Administrative clearance for publication of this editorial was provided by the Ministry of Health of South Sudan and WHO (ePub-IP-00331505-EC) to publish the result. Moreover, the Research Ethics Review Board of the Ministry of Health provided clearance for the publication of manuscript under (MoH/RERB/D.03/2022) clearance number.

Results

Routine immunisation coverage: according to the MOH DHIS data, national administrative vaccination coverage for OPV3 ranged from 43% to 77% between 2010 and 2020. Injectable polio vaccine coverage was between 1% and 53% from 2016 to 2020 (Figure 1). A disparity exists even though both vaccines are administered simultaneously (Figure 1). The routine immunisation coverage has continued to decline from 2011, reaching its lowest level in 2016 and 2019, with administered coverage at 43% and 44%, respectively. Data from the EPI survey coverage to independently assess the EPI coverage, directly from the household conducted in the country in 2012 and 2017, estimated the OPV3 coverage to be 55% and 49%, respectively. A discrepancy of 10% was noted between the OPV3 administrative coverage and survey. The WUENIC report since 2010 showed that the OPV3 coverage has been below 60% since the conflict started in 2013 and has stagnated at 50% since 2018. The OPV3 administrative coverage is usually higher than the WUENIC report.

At the state level, the OPV3 administrative coverage ranged between 12% and 124% between 2015 to 2020 (Table 1), with the three-former conflict-affected states of Jonglei, Unity, and Upper Nile accounting for states with the lowest OPV3 coverage with an 11-year average immunisation coverage of 33%, 46%, and 34% respectively. The other seven states continued to record varying and inconsistent OPV 3 coverage, with Central Equatoria and Warrap having the highest 11 years average



*IPV= Injectable Polio Vaccine Routine Immunization Admin Coverage

**OPV3 = Oral Polio Vaccine Third dose Routine Immunization Admin Coverage

***WUENIC = WHO-UNICEF Immunization Coverage

Figure 1: oral polio vaccine 3rd dose/ injectable polio vaccine immunisation coverage 2010-2020, South Sudan

Table 1: routine immunisation: oral polio vaccine 3rd dose administration coverage by state 2010 - 2020, South Sudan

State	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	11 years average
	%	%	%	%	%	%	%	%	%	%	%	%
Central Equatoria	70	103	109	98	117	102	60	73	64	50	50	81
Eastern Equatoria	83	65	62	62	64	76	44	53	52	29	41	57
Jonglei	44	61	67	64	8	18	15	13	21	21	33	33
Lakes	40	94	73	45	54	70	63	124	88	66	82	73
Northern Bahr El Ghazal	70	80	77	70	84	87	45	78	67	57	69	71
Unity	75	94	62	22	13	26	24	29	58	35	72	46
Upper Nile	49	69	57	56	23	12	19	19	21	21	31	34
Warrap	76	80	93	64	84	107	80	95	87	51	66	80
Western Bahr El Ghazal	96	68	81	91	88	79	46	70	57	66	97	76
Western Equatoria	45	55	62	56	83	77	45	69	79	94	87	68
Country	63	77	75	64	59	63	43	58	56	44	56	60

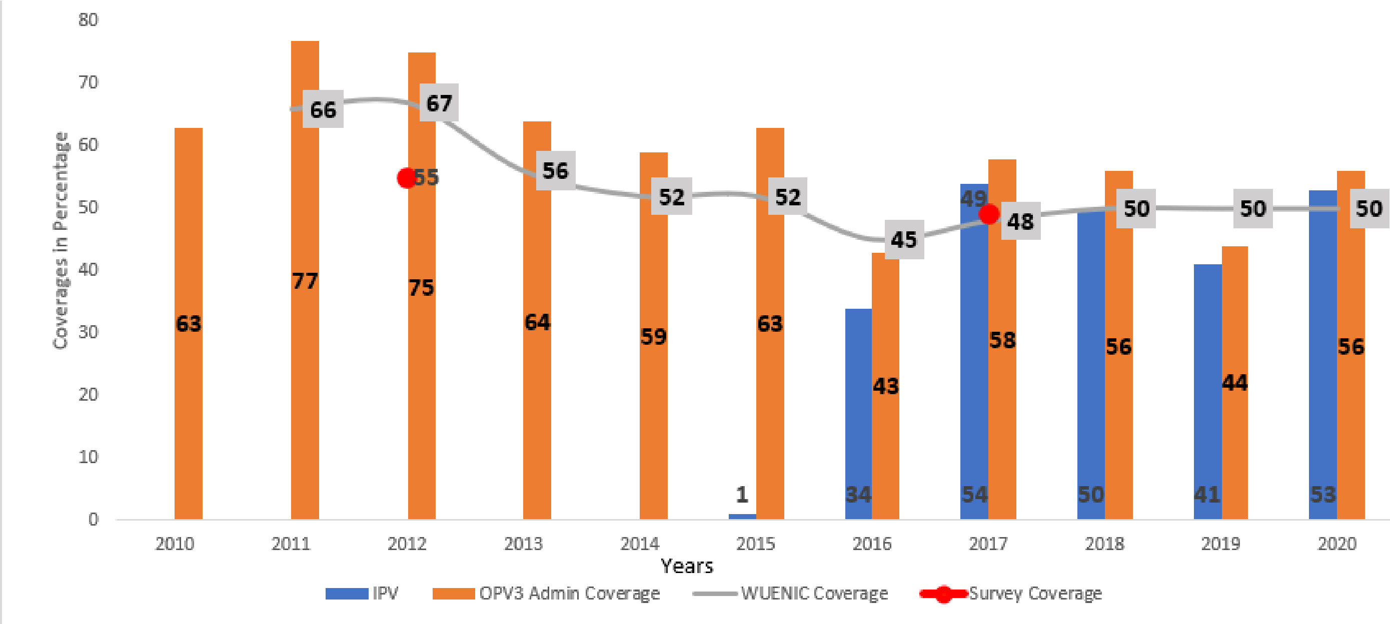
Table 2: comparison of administrative and post campaign evaluation results of supplemental immunisation activities conducted 2011 - 2020

Year	Round I (%)		Round II (%)		Round III (%)		Round IV (%)	
	Admin	PCE	Admin	PCE	Admin	PCE	Admin	PCE
2011	95	90	94	90	96	94	96	96
2012	102	95	102	94	100	93	105	94
2013	105	95	104	95	105	90	82	NA
2014	94	81	110	93	100	89	108	89
2015	112	94	111	94	110	94	111	95
2016	118	97	95	94	92	88	87	90
2017	90	88	90	89	91	86	90	88
2018	77	84	96	87	NA	NA	93	85
2019	98	89	97	92	NA	NA	NA	NA
2020	NA	NA	NA	NA	NA	NA	NA	NA

* 2020 no NID done due to the COVID 19 pandemic and lockdown; * Admin refers to administrative coverage result of the polio campaigns; * PCE refers to post campaign evaluation result of the polio campaigns; * NA refers to not applicable

coverage of 81% and 80%, respectively. In 2020 administrative routine immunisation data for OPV3 showed that 21 (26%) counties recorded coverage of OPV3 greater than 80%, 22 (28%) between 50-79.99%, 26 (33%) between 25-49.99% and 11 (14%) counties had OPV 3 coverage of less than 25% (Figure 2). Counties with the lowest coverage are found in Unity, Jonglei and Upper Nile states; however, two counties from Eastern Equatoria and Central Equatoria reported less than 25% in 2020.

Supplemental immunisation coverage: the country conducts four rounds of supplementary immunisation campaigns using polio vaccines



*IPV= Injectable Polio Vaccine Routine Immunization Admin Coverage

**OPV3 = Oral Polio Vaccine Third dose Routine Immunization Admin Coverage

***WUENIC = WHO-UNICEF Immunization Coverage

Figure 1: oral polio vaccine 3rd dose/ injectable polio vaccine immunisation coverage 2010-2020, South Sudan

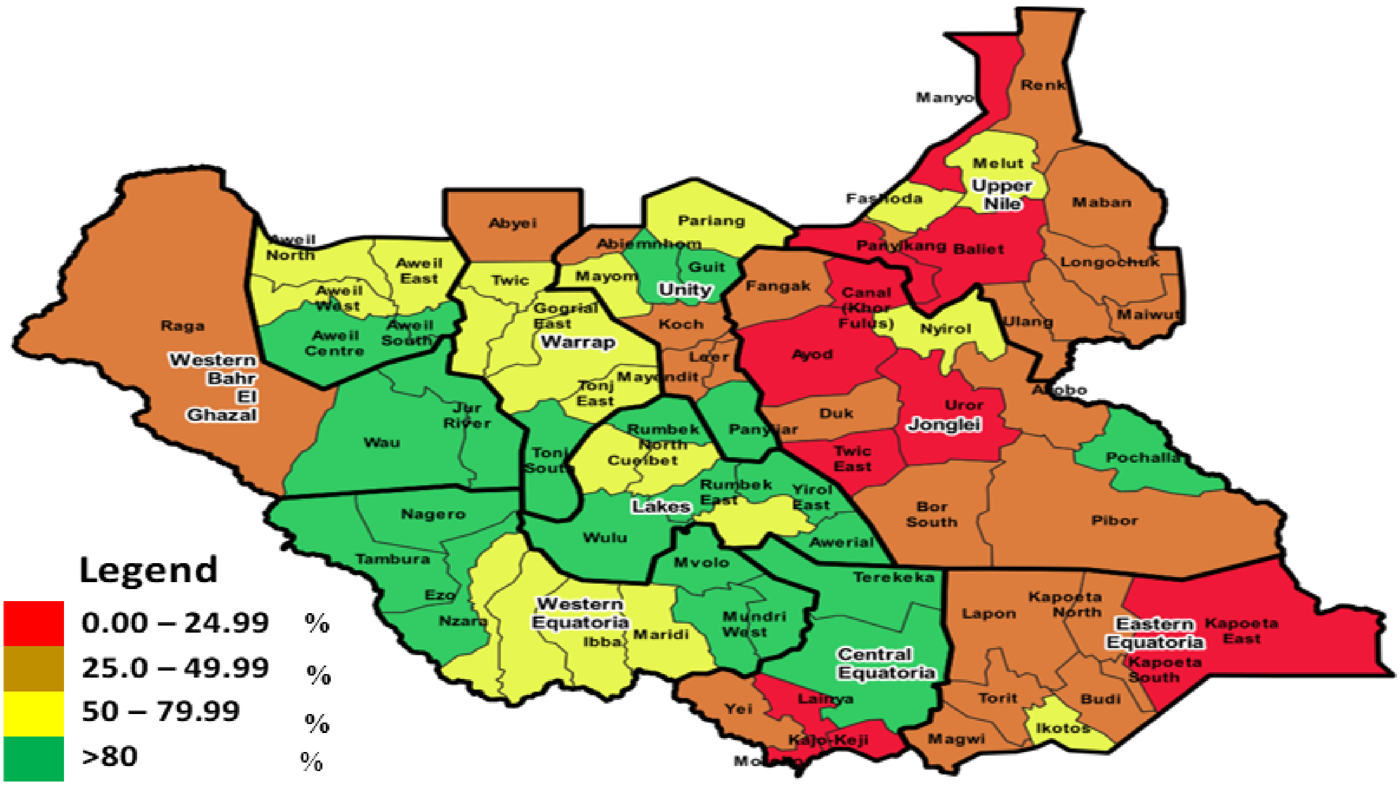


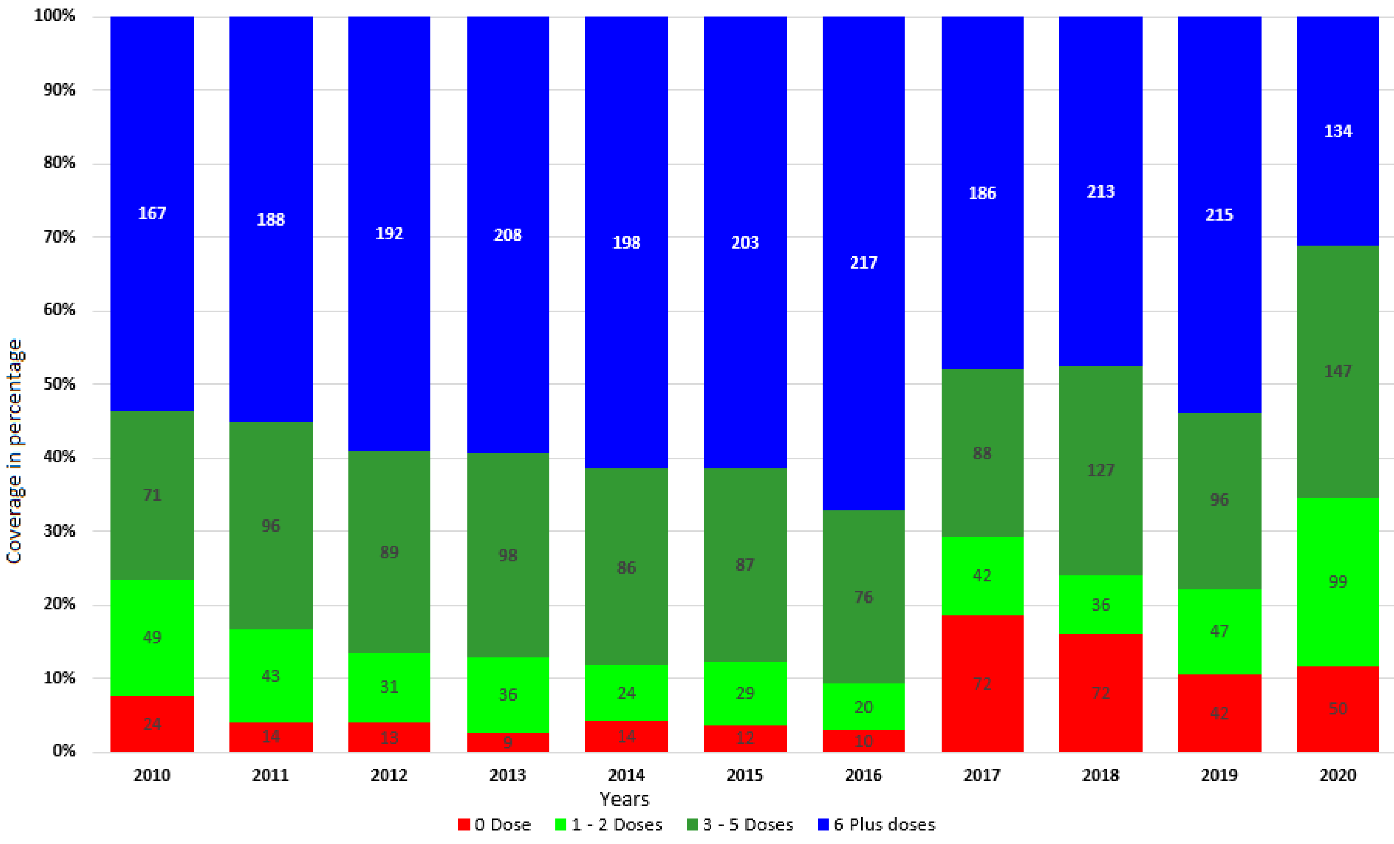
Figure 2: oral polio vaccine 3rd dose routine immunisation administration coverage by county, South Sudan 2020

yearly. All children under five of age are targeted and given two drops of the polio vaccines irrespective of the child's polio vaccination status, which boosts polio herd immunity. Results are collated against set targets, with an evaluation done to determine the coverage and quality of the campaign. The country has conducted over 32 OPV campaigns since 2011. Table 2 shows the administrative data obtained directly from the vaccinators' record and post-campaign evaluation (PCE); data obtained from independent assessors was conducted two days after the nationwide polio campaigns. The administrative results ranged from 77% to 111%, while the PCE results obtained from independent monitors ranged from 81% to 97%. Table 2 shows that the number of rounds declined from four in 2011 to two in 2019 and none in 2020. The last polio countrywide supplemental immunisation activities (SIAs) were conducted in 2019 and achieved a coverage rate of 100%; however, post-campaign evaluation (PCE) showed coverage of 92%. However, in rounds 4, 2016 and round 1, 2018, the PCE was higher than administrative data. Table 3 shows the

Table 3: results of polio campaigns 2013-2019, South Sudan

	2013 (Apr 2013)		2014 (Apr 2014)		2015 (Mar 2015)		2016 (Apr 2016)		2017 (Mar 2017)		2018 (Apr 2018)		2019 (Apr 2019)	
Name of States	**Admin %**	**PCE %**	**Admin %**	**PCE %**	**Admin %**	**PCE %**	**Admin %**	**PCE %**	**Admin %**	**PCE %**	**Admin %**	**PCE %**	**Admin %**	**PCE %**
Central Equatoria	115	95	115	76	114	99	117	86	67	87	79	87	85	93
Eastern Equatoria	116	93	102	70	116	91	107	92	106	86	102	93	101	86
Jonglei	95	96	ND	ND	ND	ND	82	ND	91	ND	86	84	99	90
Lakes	99	96	103	84	116	98	127	99	119	93	128	88	123	90
Northern Bahir Ghazal	100	92	68	72	101	92	96	97	111	93	113	92	113	93
Unity	97	96	ND	ND	ND	ND	97	ND	84	ND	114	85	109	91
Upper Nile	106	98	ND	ND	112	ND	58	ND	22	ND	38	81	33	98
Warrap	106	94	75	86	111	89	99	100	114	94	113	85	111	95
Western Bahir Ghazal	105	91	67	86	111	96	104	95	83	ND	97	91	102	88
Western Equatoria	97	97	149	86	103	94	69	89	97	86	98	86	100	88
South Sudan	**104**	**95**	**93**	**81**	**111**	**94**	**95**	**94**	**90**	**89**	**96**	**87**	**96**	**92**

*Admin = Administartive coverage; **PCE = Post campaign evaluation; ***ND = Not done



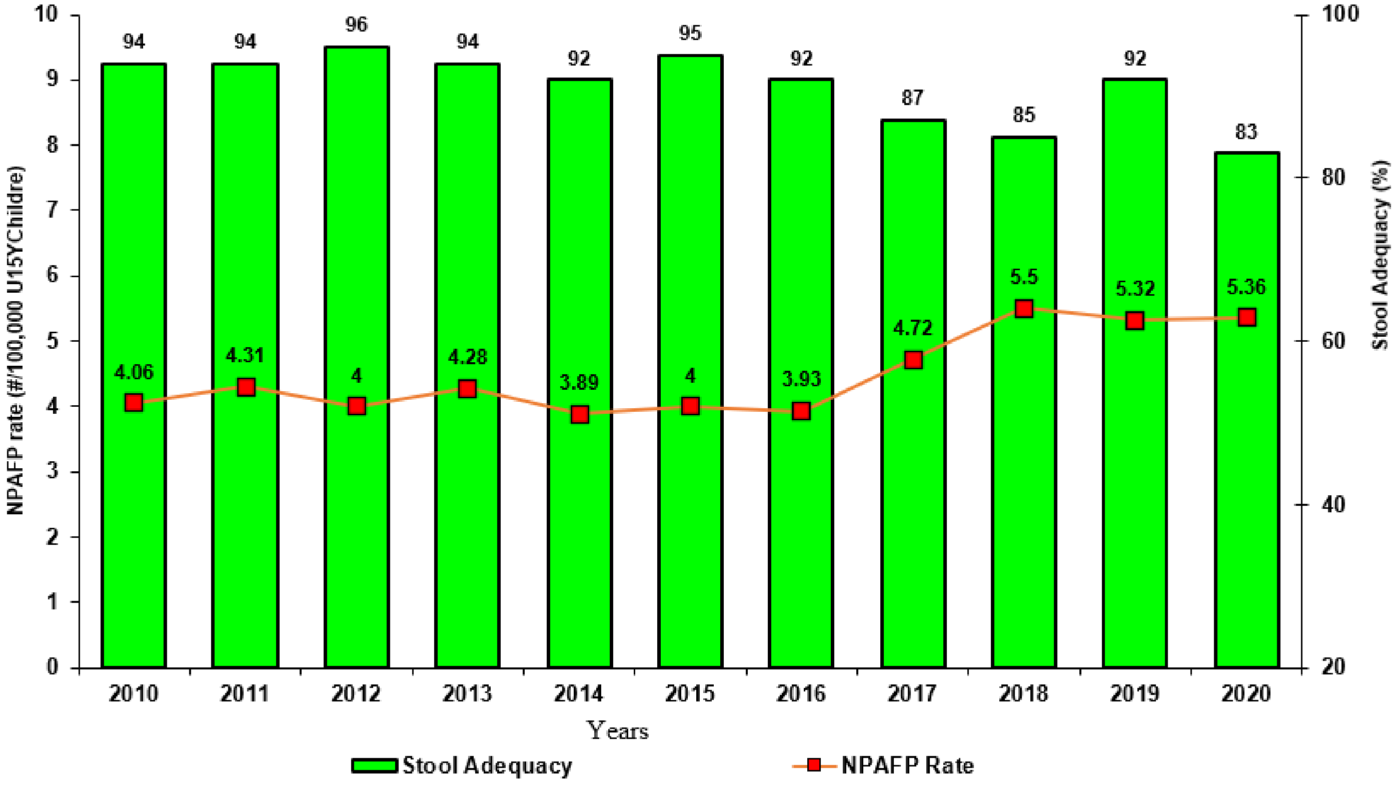
Dose = Number of OPV doses received

Figure 3: immunity profile for non-polio - AFP cases (6-59 months) 2010-2020 South Sudan

administrative and PCE results by state, with Upper Nile recording the lowest admin coverage of 22% and Central Equatoria with the highest admin coverage of 117%. Table 3 also showed that post-campaign evaluation was not conducted for some of the conflicts affected states rounds even though an SIA was done.

Immunity profile for non-polio AFP cases: a dataset of AFP surveillance comprised 3970 AFP cases notified from 2010 to 2020, of which 3161 (80%) of the cases were aged 0 to 59 months. Overall, 3182 (80%) of notified AFP cases had received more than three doses of the oral polio vaccine, and the polio vaccination status was zero for 332 (8%) of the AFP cases (Figure 3). The proportion of AFP cases with more than three OPV doses varied between 65% and 91% between 2010 to 2020, with the lowest rates observed in 2020 (65%), while the highest percentage was observed in 2016 (91%).

AFP surveillance indicators: from 2010 to 2020, South Sudan maintained the two main indicators of AFP surveillance, well above recommended standard, with the NP-AFP rate above 3/100,000 children under 15 years of age and reaching an NP-AFP rate of 5.36/100,000 for 2020, with the NP-AFP ranging from 3.89 to 5.5, with the highest number reported in 2018 (Figure 4). Likewise, stool adequacy has been above the certification level (80%) since 2010 and was 83% for 2020, with the best performance recorded in 2019. The URVI laboratory reports above the recommended standard of 10% NPENT since 2010, with the highest NPENT rate of 21.5% recorded in 2019 and the lowest NPENT rate of 13.2% recorded in 2018 (Table 4).



**NPAFP = Non Polio Acute Flaccide Paralysis Rate

Figure 4: the two main acute flaccid paralysis surveillance indicators 2010-2020, South Sudan

Table 4: non-polio enterovirus rate of acute flaccid paralysis samples 2010-2020, South Sudan

Year	Number of acute flaccid paralysis cases	Number of cases with enteroviruses	Non- polio enterovirus rate
2010	309	43	13.9%
2011	341	56	16.4%
2012	324	66	20.4%
2013	350	74	21.1%
2014	318	51	16.0%
2015	331	60	18.3%
2016	323	67	20.7%
2017	388	68	17.5%
2018	447	59	13.2%
2019	400	86	21.5%
2020	429	79	18.4%

Discussion

South Sudan's polio eradication program has seen its share of successes and setbacks, with routine immunisation suffering the most. Two vaccines, the OPV and the IPV protect against wild poliovirus and are both routinely administered in the country [29,30]. The outcomes of this study indicated that routine immunisation coverage continues to drop and is significantly below the required coverage of OPV3 and IPV of 80%. WUENIC reports and two independent EPI coverage surveys undertaken in 2012 and 2017 corroborate this conclusion [31,32]. The consistent low coverage between 2015 and 2020 can be attributed primarily to the conflict. This has weakened the health system, particularly at the peripheral level, with far-reaching negative consequences for engaging, retaining, and motivating adequate skilled health workers to deliver quality immunisation services [33,34]. However, the severe dips in 2014 and 2016 are explained by the massive conflict in 2013. Similar findings have been reported in conflict-affected nations such as the Syrian Arab Republic and Ukraine, with vaccination coverage declining by 50% [35].

Many health services in the country are provided in collaboration with partner organisations. However, in 2019, there was a delay in contract signing between the MOH and these partners, affecting many health services for nearly six months, as evidenced by the lowest coverage ever reported in the country that year. The three-former conflict-affected states of Jonglei, Unity and Upper Nile bore the major conflict's brunt. They continuously reported the lowest routine immunisation coverage, with most health facilities vandalised. There are also challenges in the vaccine supply chain, depleted human resources, and high population displacement and movement, with none of their counties reporting coverage above 80%. The increased coverage of >100% in Central Equatoria and Warrap states in 2013 and 2014 can be attributed to the massive population movement to safer havens. The disparity between administrator coverage, the EPI survey, and WUENIC demonstrates that data quality is a concern. The country is now conducting training sessions and quarterly data quality assessments to identify and close this gap. The country's general poor coverage is comparable to that of several other nations involved in the conflict, including Pakistan, Afghanistan, Yemen, Somalia, and the Democratic Republic of the Congo [36,37]

It is critical to recognise that the three states of Unity, Jonglei, and Upper Nile will require a more tailored strategy to increase RI coverage and mitigate the danger of polio epidemics. These states have suffered the most from the conflict, as these were where the fighting was most intense as facilities were burnt and people displaced with its attendant poor RI coverage. The country undertakes Supplemental Immunisation Activities (SIAs) through National Immunisation Days (NIDs), each cycle targeting about 3 million children aged <5 years to supplement the herd immunity produced by routine vaccination. These campaigns occur 4 times a year and are conducted door-to-door with vaccinators stationed at vehicle parks, schools, and border crossings to guarantee no child is missed. This approach has been highly successful, with coverage rates

>85% commonly reported and verified by third-party post-campaign evaluations. It is worth noting that NIDs remain the only source of immunisation services in many sections of the country. This is supported by an analysis of children <5 years of age reporting AFP, which indicates that, on average, 80% of AFP cases received three or more doses during the polio campaigns from 2010 to 2020. Population immunity to polio may be higher than reported administrative coverage due to the numerous polio campaigns conducted.

Only three campaigns have been conducted in the last three years, two of which were subnational immunisation days targeting states with low RI administrative coverage. This has led to a reduction in the number of < 5-year-old children from AFP cases receiving three or more doses of OPV vaccine. This figure was lowest in 2020, with only 65% of reported AFP cases receiving three or more OPV doses due to the absence of polio campaigns which were halted due to the COVID 19 pandemic [38]. Because of campaign reductions, the decline in herd immunity will make the country vulnerable and or susceptible to another WPV importation, as reported in 2006 and 2008. Administrative results for the campaigns show that there is not much difference in coverage between the states, except for Upper Nile which consistently reported low coverage due mainly to access and insecurity. At the peak of the conflicts from 2014 to 2016, nationwide polio campaigns were not held for the former conflict states of Jonglei, Upper Nile and Unity as access was impossible due to insecurity; however other tailored approaches such as subnational campaigns and hit and run were conducted. The campaign's administrative results can be attributed to the quality of the pre-implementation activities, including micro plans, adherence to team selection criteria when recruiting team members, appropriate social messages with minimal non-compliance, and collaboration with partners led by the MOH. Also, the use of innovative tools such as the ODK for reporting performance and, most importantly, institutional memory, as the country has extensive experience in conducting similar campaigns. The high coverage in polio campaigns has proven challenging to transfer to RI, and the same has been recorded in other conflict-affected countries such as Somalia and warrants additional investigations [39].

South Sudan has consistently met the two core AFP surveillance indicators between 2010 and 2020, with improvements noted in the last three years attributed to the scaling-up of the community surveillance system in hard-to-reach states by the CORE group and access for humanity. Innovations such as the Open data kit, which uses mobile phones to provide real-time data for action and serve as the foundation for the programme's accountability framework [6]. The country reported 12 wild poliovirus outbreaks in 2004-2005 and 64 in 2008-2009. It reported 2 and 50 circulating Vaccine-Derived Polio Virus (cVDPV) outbreaks in 2014 and 2020, respectively, demonstrating a sound surveillance system while pointing to low herd immunity against polio virus.

South Sudan's AFP surveillance indicators are higher than the regional average for East and Southern African countries, with an NP-AFP at 5.1 and stool adequacy at 90% compared to the region's NP-AFP at 3.3 and stool adequacy at 86% [40]. This is due to the significant investment made by donors and the GPEI collaboration and the limited reliance on the current government health system, which is based on a passive surveillance system. Conflicts appear to have little effect on the ability to detect AFP cases and meet standard indicators, with similar results reported in countries such as Pakistan, Afghanistan, and Nigeria [39,41,42] The program's ability to detect and report the presence or absence of poliovirus is contingent upon the laboratory's ability to isolate and identify enteroviruses from AFP samples. These are affected by the reverse cold chain, with a 10% NPEV isolation rate serving as a reference point [43]. The country met the criterion for this indicator, further establishing the credibility of the country's polio activities despite delays in stool transfer to WHO-accredited laboratories caused by erratic flight schedules and cancellations, particularly during the rainy season. Transportation of AFP samples to the URVL on time continues to be the most significant barrier to the country's polio program. However, it can be addressed by ensuring that samples are adequately preserved until transported to the laboratory.

The findings of this study should be interpreted in the context of several limitations. First is the incompleteness and varied timeliness of the routine immunisation data. Second, the target population used remains data from the extrapolated 2008 Census. To overcome this, the RI data was the final database submitted in subsequent years, e.g. the 2020 data used was sourced from the DHIS database of March 2021. Also, data from the polio campaign micro plans collated from the community via a bottom-top process are used for campaign planning. For surveillance data, incomplete variables were excluded from any analyses; also, we conducted data harmonisation between different partners for consistency. The country routinely validates all AFP cases by senior and trained personnel. The introduction of the ODK in 2017 has helped mitigate some of the above limitations and the monthly data harmonisation at the National, state, and county levels. Second, the AFP cases reported through the polio surveillance system may not reflect the actual numbers of all AFP cases in the country. The major factors responsible are no reporting or investigation of these cases by the caregivers or health workers due to lack of knowledge and difficulty reporting due to poor or no mobile network. These are mitigated by yearly training of health workers and community informants. Third, the high NP-AFP rate does not imply that these are all true AFP cases, but this has been addressed by validating all AFP cases by senior WHO officers.

Conclusion

South Sudan continues to report low immunisation coverage threatening polio achievements. Polio eradication is possible even in conflict settings with limited health service capabilities; however, post-certification guidelines set by GPEI must be followed to avoid a resurgence of the poliovirus. As GPEI comes to an end, it is essential to bring innovative ideas to improve routine immunisation coverage quickly. Of concern is the reduction in the number of polio campaigns which provides an opportunity for children to be immunised with OPV and an opportunity for sensitisation of caregivers on the need for immunisation.

Recommendations: we recommend that these polio campaigns be maintained with at least two national campaigns every year until RI coverage improves. Human resources are the most asset of the polio programme and need to be adequately supported as the GPEI ramps down with a decline in funding. The AFP surveillance system must be maintained post-certification, as the country's IDSR moves from the passive mechanism to the active search done for AFP surveillance. As the country continues to build and improve the healthcare infrastructure, there is a need for continued AFP surveillance to detect and respond to poliovirus outbreaks Tailored strategies such as Periodic Intensified Routine Immunisation (PIRI), Enhanced mobile and outreach interventions, missed opportunities for vaccination need to be adopted for RI use in the country, and proper compensation and security provided for health workers.

What are the implications for Public health?

Polio free certification is just the first of many steps towards achieving a polio-free world. Conflict countries like South Sudan still need to conduct high-quality polio campaigns, strengthen its AFP surveillance system for many more years as the current routine immunisation coverage will be unable to provide herd immunity required to stop the importation of the poliovirus in the country.

What is known about this topic

- As of 2020, only one WHO region is yet to be certified wild poliovirus free, and the countries in this region (Afghanistan and Pakistan) along with South Sudan have suffered years of conflict; however, South Sudan has succeeded in getting its claim of being wild poliovirus free validated and accepted;
- The country continues to report low routine immunisation coverage, less than the expected 80% for all vaccines, including both OPV and IPV
- Injectable polio vaccine was introduced in 2016 following the switch from tOPV to bOPV.

What this study adds

- It elaborates how WPV free certification can be achieved even in conflict countries and how the application of tested polio strategies can stop the virus on its track;
- The importance of polio campaigns in maintaining herd immunity;
- It identifies states and counties that need to be prioritised where resources are limited.

Competing interests

The authors declare no competing interests.

Authors' contributions

SM conceived and drafted the article and systematically reviewed the literature, while AAT, MF, BEB, GUA, IMB, JMT, AA, JLW, SOO, MN, FN, KKB, PM, and OOO critically reviewed and approved the final version of the study.

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Research

Epidemiological characterization of COVID-19 in displaced populations of South Sudan

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Abstract

Introduction: South Sudan is facing a protracted humanitarian crisis with increasing population vulnerability. The study aimed to describe the epidemiology of COVID-19 in displaced populations in South Sudan.

Methods: the study involved the internally displaced populations (IDP) in Bentiu IDP camp, South Sudan. This was a descriptive cross-sectional study involving individuals that met the COVID-19 probable and confirmed case definitions from May 2020 to November 2021. Case data were managed using Microsoft Excel databases.

Results: the initial COVID-19 case in Bentiu IDP camp was reported on 2 May 2020. The overall cumulative attack rate (cases per million) was 3,230 for Bentiu IDP and 1,038 at the national level. The COVID-19 Case Fatality Ratio (CFR) among the IDPs was 19.08% among confirmed and 1.06% at the national level. There was one wave of COVID-19 transmission in the IDPs that coincided with the second COVID-19 wave in South Sudan for the period May 2020 to November 2021. Adult males aged 20-49 years were the most affected and constituted 47.1% of COVID-19 cases. Most severe cases were reported among adults 60-69 years (53%) and ≥ 70 years (80%). The risk of COVID-19 death (deaths per 10,000) increased with age and was highest in patients aged ≥ 60 years at 64.1. The commonest underlying illnesses among COVID-19 deaths was HIV-related illness, heart disease, and tuberculosis.

Conclusion: COVID-19 constitutes a significant impact on internally displaced populations of South Sudan. The COVID-19 response in displaced populations and the high-risk groups therein should be optimized.

Introduction

South Sudan has braced a protracted humanitarian crisis characterized by cycles of violence, displacement, severe food insecurity, flooding, and disease outbreaks like cholera, yellow fever, hepatitis E virus, and other public health emergencies [1-4]. These persistent shocks have had a compounding effect, eroded coping capacities, increased vulnerabilities, and increased the risk of excess morbidity and mortality [1]. The internally displaced population (IDP) in South Sudan has been increasing and is estimated at 2 million people [1]. Bentiu IDP camp was established in 2014 as a protection of civilians camp but transitioned into an IDP camp in March 2021 and is the largest IDP camp in the country with an estimated population of 107,130 people [5]. In 2021, an outbreak of hepatitis E virus was confirmed in Bentiu IDP camp and this was attributed to inadequate access to safe water and sanitation that was below sphere standards [6]. While a multi-cluster hepatitis E virus outbreak response is underway these efforts have been constrained by new displacements into the camp due to the devastating flooding that has affected over 200,000 people in Unity state [7].

It is within this context that South Sudan is responding to the raging COVID-19 pandemic that has not spared displaced populations in South Sudan. South Sudan was one of the last countries to confirm Coronavirus disease 2019 (COVID-19) and reported its first case on 5th April 2020. As of 10th December 2021, a total of 12,873 confirmed COVID-19 cases including 133 deaths (Case Fatality Ratio (CFR) 1.03%) have been reported [8]. COVID-19 patients manifest with respiratory illness that varies from asymptomatic or mild illness to moderate and severe disease requiring hospitalization [9,10].

The impact of COVID-19 was therefore expected to be unprecedented in low-income settings and displaced populations [11]. The adverse COVID-19 outcomes would be driven by high transmission in extended households, overcrowding in IDP camps, inadequate access to water and sanitation, and super spreading events within the context [12]. Moreover, the high burden of noncommunicable diseases like uncontrolled hypertension, malnutrition, tuberculosis, and HIV in low income and forced displacement settings was expected to increase the risk of severe disease, demand on admission and critical care, with the potential of overburdening systems and constraining access to routine healthcare and immunization for common causes of morbidity and mortality in children and women of childbearing age [13].

The overall control of COVID-19 is premised on strong surveillance and testing capacities, isolation and effective treatment of cases, quarantine of contacts, vaccination with priority to high risk groups, and communitywide implementation of public health social measures like stay home lockdowns, barring of congregations and superspreading events, mask use in closed and public places, regular hand washing, and social distancing [14]. However, in low income, fragile, and vulnerable settings, extended population wide COVID-19 restrictions have been associated with negative social and economic implications with erosion of livelihoods and coping capacities [15]. Hence the alternative of time limited movement restrictions, community led shielding of high risk individuals, self-isolation of mild to moderately ill individuals, and physical distancing were proposed as balanced approaches in low income, fragile, and vulnerable settings [15]. More importantly, the equitable distribution of countermeasures like vaccines, diagnostics, and therapeutics is critical for optimal COVID-19 control in forced displacement settings [15].

We present here the epidemiology of COVID-19 in displaced populations in South Sudan as a precursor for evidence based and targeted pandemic response. The information generated will facilitate equity in the distribution of medical and public health countermeasures to displaced populations and the high-risk groups therein to avert catastrophic outcomes.

Methods

Study area and population: the study was conducted in South Sudan and involved the internally displaced population living in Bentiu IDP camp, Rubkona county, Unity State. The camp was established in December 2013 and as of June 2021, the registered population stood at 107,130 individuals living in 15,716 households [5]. As part of the COVID-19 pandemic response, suspect COVID-19 cases were identified, tested, isolated, and followed up guided by the national standard operating procedures (SoP) for COVID-19 surveillance [16]. The present study identified all the confirmed COVID-19 cases reported by the Ministry of Health (MoH) in Bentiu IDP camp from 5th April to 7th November 2021. The South Sudan COVID-19 surveillance (SOP) defined COVID-19 cases as follows [16]. A suspect COVID-19 case was defined as any person presenting with at least two of the following symptoms: fever (>38°C), chills, rigors, myalgia, headache, sore throat, fatigue, vomiting, diarrhea, sudden loss of taste, sudden loss of smell; OR at least one of the following symptoms: severe cough, shortness of breath, or difficulty breathing; OR severe respiratory illness; AND no alternative more likely diagnosis.

A probable COVID-19 case was defined as a suspect case for whom testing for COVID-19 was inconclusive OR a suspect case for whom testing could not be performed for any reason. A confirmed COVID-19 case was defined as a person with laboratory confirmation of SARS-CoV-2 (by Nucleic Acid Amplification Test (NAAT), irrespective of clinical signs and symptoms OR a person with a positive SARS-CoV-2 Antigen-RDT AND meeting either the probable or suspect case definition OR an asymptomatic person with a positive SARS-CoV-2 Antigen-RDT who is a contact of a probable or confirmed case. A COVID-19 death was defined as a death from a clinically compatible illness in a probable or confirmed COVID-19 case, unless there is a clear alternative cause of death that cannot be related to COVID-19 for example trauma. There should be no period of complete recovery between illness and death [17,18].

Inclusion criteria: all individuals who met the case definition of a COVID-19 probable or confirmed case and a COVID-19 death in the Bentiu IDP COVID-19 case and mortality database from 5th April 2020 to 7th November 2021 were included in the study.

Exclusion criteria: all individuals who did not meet the case definition of a COVID-19 probable or confirmed case definition and a COVID-19 death that were not listed in the Bentiu IDP COVID-19 case and mortality database from 5th April 2020 to 7th November 2021 were excluded from the study.

Study design: this was a descriptive cross-sectional study involving all individuals that met the inclusion criteria. The study used both quantitative data from the national and Bentiu IDP COVID-19 case and mortality database and other descriptive and context information from the national weekly COVID-19 epidemiological bulletin and other state level COVID-19 and humanitarian situation updates.

Sample size and methods: all the individuals that met the COVID-19 probable and confirmed case definition and who were included in the Bentiu IDP COVID-19 case and mortality database during the study period were included in the study.

Data collection: all case investigations and data collection were integrated into and started with the investigation of the respective suspect and probable COVID-19 cases using the national COVID-19 case investigation form that also documented clinical outcome as recovered or died. Communities reported suspect COVID-19 cases through a telephone hotline, to the nearest health facility, or to designated COVID-19 sentinel sites, or other designated COVID-19 testing sites including private health facilities and laboratories. Probable or confirmed COVID-19 were also identified among contacts to confirmed or probable COVID-19 cases, as part of pretravel screening, or though screening in high-risk populations like workplaces (health facilities), schools, other institutions, and COVID-19 field investigations by rapid response teams. COVID-19 case data was entered into paper-based COVID-19 case investigation form. Verbal autopsies were conducted for probable COVID-19 deaths. Electronic entry of case based data into a Microsoft Excel based database occurred at designated COVID-19 designated GeneXpert sites and at the Data Management Unit (DMU) in the Public Health Emergency Operations Center (PHEOC) in Juba. As part of the current study, the COVID-19 weekly epidemiological bulletins and humanitarian situation reports were reviewed to obtain descriptive and contextual information requited to explain the observed epidemiological statistics.

Data management and analysis: all COVID-19 case, and mortality data were managed using Microsoft Excel databases at the national and State level. However, at the time of writing this paper, the COVID-19 DHIS 2 module was being rolled out to support all the COVID-19 pandemic health information needs including the management of COVID-19 case based data. We used the Bentiu IDP, and national level COVID-19 Microsoft excel database files to summarize the frequency distribution of cases and deaths by gender, age, and time. To assess the severity of illness by age, we ran the frequency distribution of case admissions to Bentiu IDP isolation facility by 10-year age groups. The risk of death from COVID-19 by age was computed as the number of deaths per 10,000 Bentiu IDP population for each of the 10-year age categories. We used the Bentiu IDP mortality line list to compute the overall crude mortality rate (CMR) (deaths per 10,000 population per day) and the under-five mortality rate (U5MR) (deaths per 10,000 population of under-fives per day) in the IDP camp [19]. To assess the impact of COVID-19, we compared the CMR and U5MR prior to the pandemic (in 2019) to the rates during the pandemic (2020 and 2021). We ran a frequency distribution to identify the common underlying illnesses among deceased COVID-19 cases in the IDP camp.

Quality control: trained COVID-19 response teams including rapid response teams, contact tracing teams, sentinel site teams, and clinicians at designated public and private clinics and laboratories collected case based data using a simplified COVID-19 case investigation form. A dedicated team of Ministry of Health data managers in the PHEOC Data Management Unit were mandated to review and update the records for completeness and to clean the data on a daily basis. The case based records were reviewed for completeness and consistence clinical and epidemiological information with the COVID-19 case and death classification.

Ethics approval and consent to participate: the study used existing COVID-19 case based data and context information from routine COVID-19 epidemiological reports and humanitarian situation reports. The study is therefore regarded as operational research for which administrative clearance was provided by the national COVID-19 incident manager to foster evidence based response to the pandemic. The paper was also cleared by WHO under ePub number (ePub-IP-00332814-EC). Moreover, the Research Ethics Review Board of the Ministry of Health provided clearance for the publication of manuscript under (MoH/RERB/D.03/2022) clearance number.

Results

The initial COVID-19 case in Bentiu IDP camp was reported on 2th May 2020 with a total of 346 cases reported up to 7th November 2021. The COVID-19 cases reported in the IDP camp included 309 confirmed cases, 37 probable cases, and 66 deaths. The COVID-19 Case Fatality Ratio (CFR) among the IDPs was 19.08% among confirmed and probable cases and 9.39% among confirmed cases. During the corresponding period, 12,514 confirmed cases including 133 deaths were reported at the national level with a CFR of 1.06%. Cumulative attack rate (cases per million) was 3,230 for Bentiu IDP and 1,038 at the national level Table 1.

COVID-19 case trends: as seen from Figure 1, the initial confirmed COVID-19 cases were reported in week 18, 2020, four weeks after the initial case was notified in South Sudan. The initial case reported history of travel outside the IDP camp within 14 days of illness onset. Sporadic transmission continued up to week 4, 2021 with no obvious travel history and minimal secondary cases among investigated contacts. Steady and clustered transmission started in week 5, 2021, with the 7-day moving average rising steeply from 1 case at the beginning of week 5, 2021 to a peak of 9.1 cases at the end of week 6, 2021. The COVID-19 cases in the IDP camp declined steadily thereafter, the decline coinciding with intensification of COVID-19 control measures that included an imposition of a time limited partial lockdown with restrictions on travel, gatherings, closure of schools and churches, as well imposition of curfew hours.

At the national level, the initial cases were reported in week 4 of 2020 and were associated with travel outside the country (Figure 2). Sporadic transmission with no clustering and few secondary cases among investigated contacts continued up to week 18 of 2020 when cases started rising steadily (Figure 2). The cases then rose from 23 cases per week in week 18, 2020 to a peak of 447 cases in week 22 of 2020, also the peak of the first wave of transmission in the country (Figure 2). The second wave of transmission in South Sudan started in week 3, 2021 reaching a peak of 1,369 cases in week 7, 2021 with the cases declining steadily thereafter (Figure 2). The peak of the second wave of transmission in South Sudan exceeded the first wave by 206% and occurred one week after the peak transmission in Bentiu IDP. The second wave of COVID-19 transmission was associated with a steep rise in cases and also coincided with the isolation of the eta SARS-CoV-2 variant in South Sudan.

Case distribution by sex and age: most of the COVID-19 cases in Bentiu IDP were reported among males 210 (60.7%). During the same period, 6,919 (71.5%) of the cases were reported among the males countrywide. Most of the COVID-19 cases in Bentiu IDP camp were reported among males aged 20-49 years who accounted for 47.1% of the total cases. Females 20-49 years accounted for 25.1% of the cases reported in Bentiu IDP camp (Figure 3). Most of the cases reported at the national level were males 20-49 years who constituted 56.1% of the cases reported countrywide. Females 20-49 years accounted for 21.7% of the cases reported countrywide.

Severity of COVID-19 illness: admissions to Bentiu IDP isolation facility were limited to moderately ill patients with underlying chronic illness as well as severely ill and critically sick patients. Of the 309 patients with

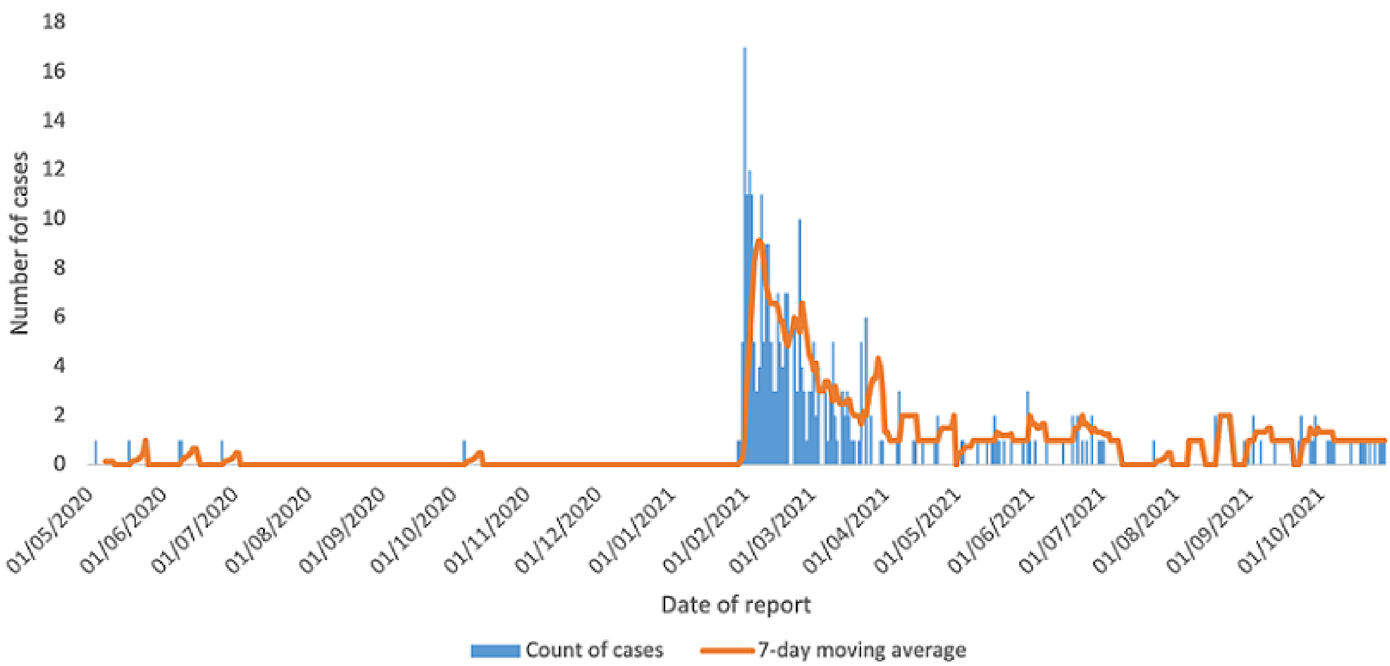

Figure 1: COVID-19 confirmed cases in Bentiu IDP, week 18, 2020 to week 43, 2021

Table 1: COVID-19 confirmed cases by location, 5 April 2020 to 7 November 2021						
Location	**COVID-19 status**	**Alive**	**Died**	**Total cases**	**Cumulative attack rate (cases/ million)**	**Case Fatality Ratio (CFR)**
Bentiu IDP	Confirmed	280	29	309	2,884	9.39%
	probable	0	37	37	345	100.00%
	Probable/confirmed	280	66	346	3,230	19.08%
National level	Confirmed	12,381	133	12,514	1,038	1.06%

documented admission status, 104 (34%) were admitted to the isolation facility (Table 2). The age groups with the highest proportion of cases admitted were 60-69 years 9 (53%) and ≥70 years 16 (80%) (Table 2).

Deaths among COVID-19 cases: a total of 66 deaths were reported in Bentiu IDP during the reporting period. Most deaths in Bentiu IDP were reported among the males 38 (57.6%). The age group with the highest proportion of COVID-19 deaths was ≥60 years with 29 (78.4%). Males aged 70 years and above accounted for the highest proportion of deaths 19 (18.2%), followed by females aged 60-69 years of age 8 (12.1%) (Figure 4). The risk of COVID-19 death (deaths per 10,000) rose with age from 2.7 among the 10-19 year old patients to 64.1 in patients aged ≥ 60 years (Figure 5). Among the admitted COVID-19 cases, the highest proportion of deaths were reported among the 50-59 year age group (66.7%) and 60-69 year age group (55.6%).

Crude Mortality Rate (CMR) and Under Five Mortality Rate (UFMR) in Bentiu IDP: the CMR and U5MR (deaths per 10,000 population per day) were computed each of the years 2019, 2020, and 2021 (up to 7 November 2021). As seen from Table 3, there were marginal increases with no significant changes in the CMR and U5MR in Bentiu IDP during 2019, 2020, and up to 7th November 2021.

Underlying illnesses among COVID-19 deaths: among the 66 COVID-19 deaths reported in Bentiu IDP during the reporting period, 38 (57.6%) had a documented underlying illness. The most common underlying illnesses reported among COVID-19 deaths in Bentiu IDP included HIV related illness (HRI), heart disease, tuberculosis, renal disease, and stroke (Table 4).

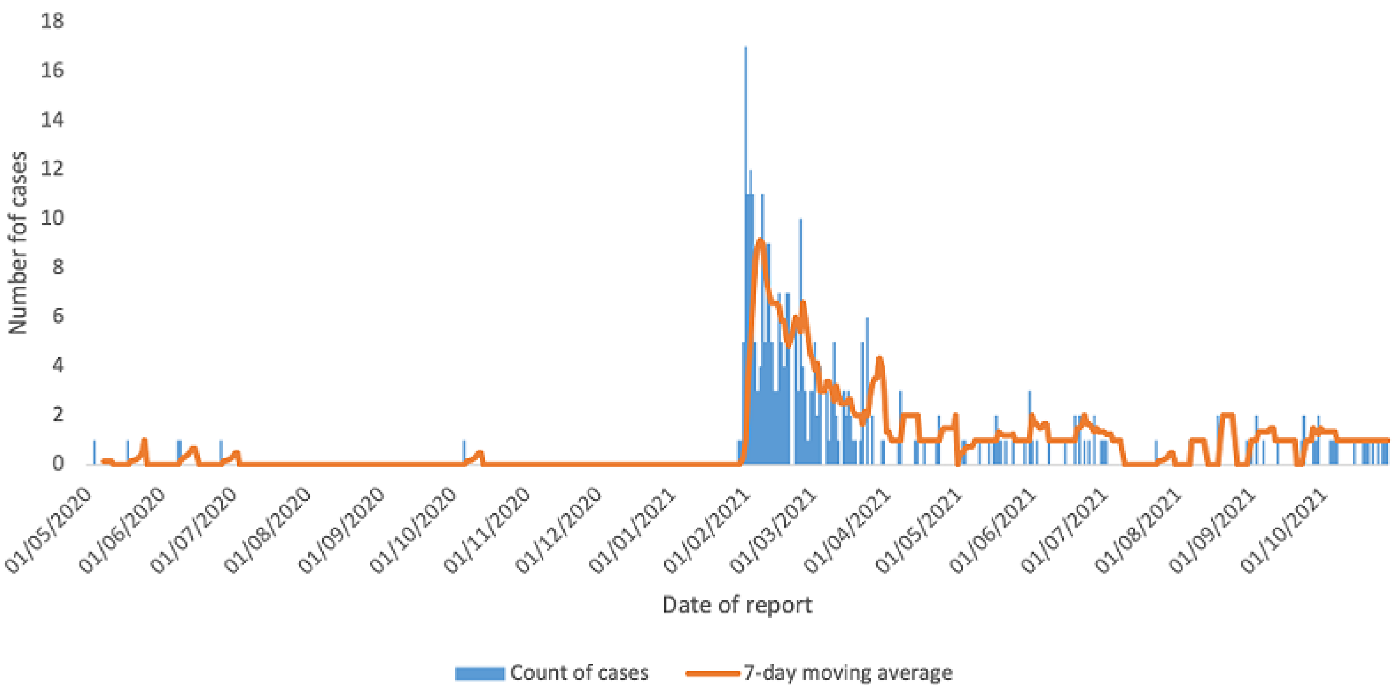

Figure 2: COVID-19 confirmed cases in South Sudan, week 1, 2020 to week 43, 2021

Table 2: COVID-19 admission to Bentiu IDP isolation facility, week 18, 2020 to week 43, 2021				
Age (yrs)	**Admission to hospital**		**Total cases**	**Admissions (%)**
	No	**Yes**		
0-9yrs	1	1	2	50%
10-19yrs	9	4	13	31%
20-29yrs	43	21	64	33%
30-39yrs	89	31	120	26%
40-49yrs	37	19	56	34%
50-59yrs	14	3	17	18%
60-69yrs	8	9	17	53%
70+yrs	4	16	20	80%
Grand Total	**205**	**104**	**309**	34%

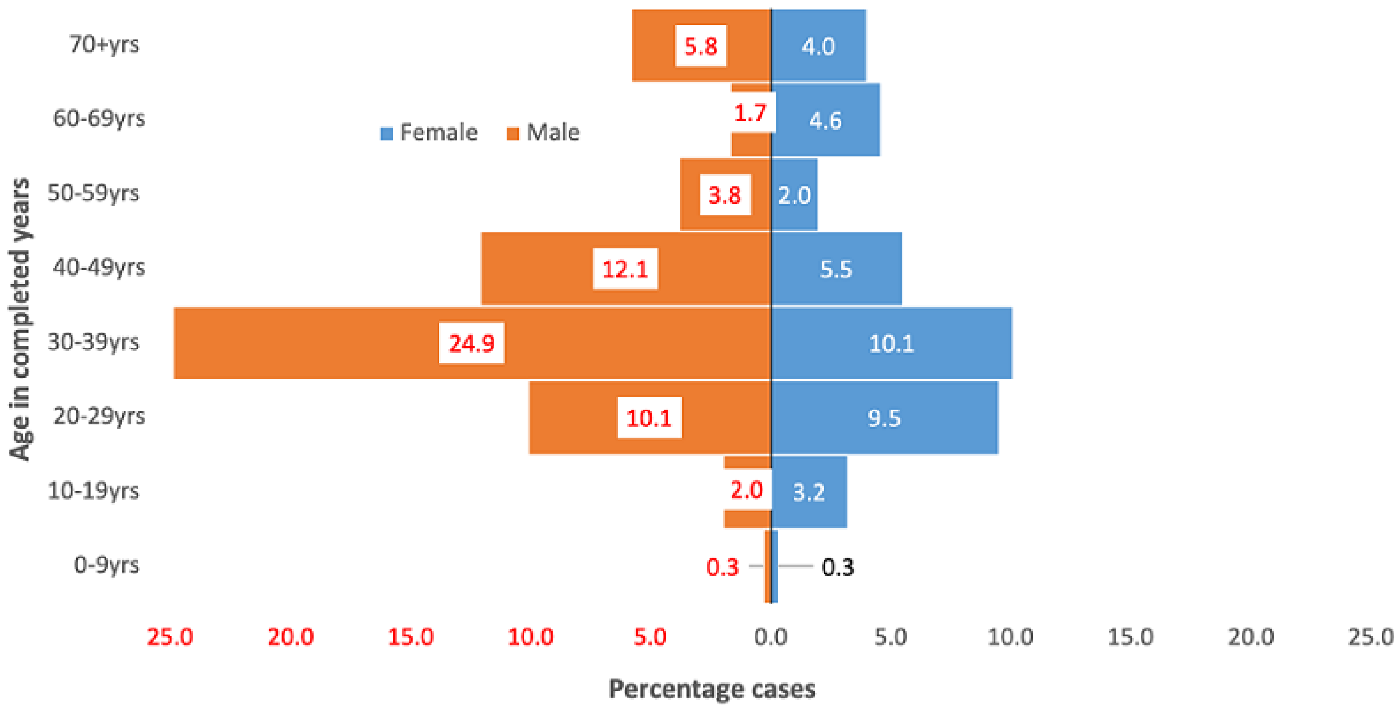

Figure 3: COVID-19 cases in Bentiu IDP camp, Unity state, 2 May 2020 to 7 November 2021

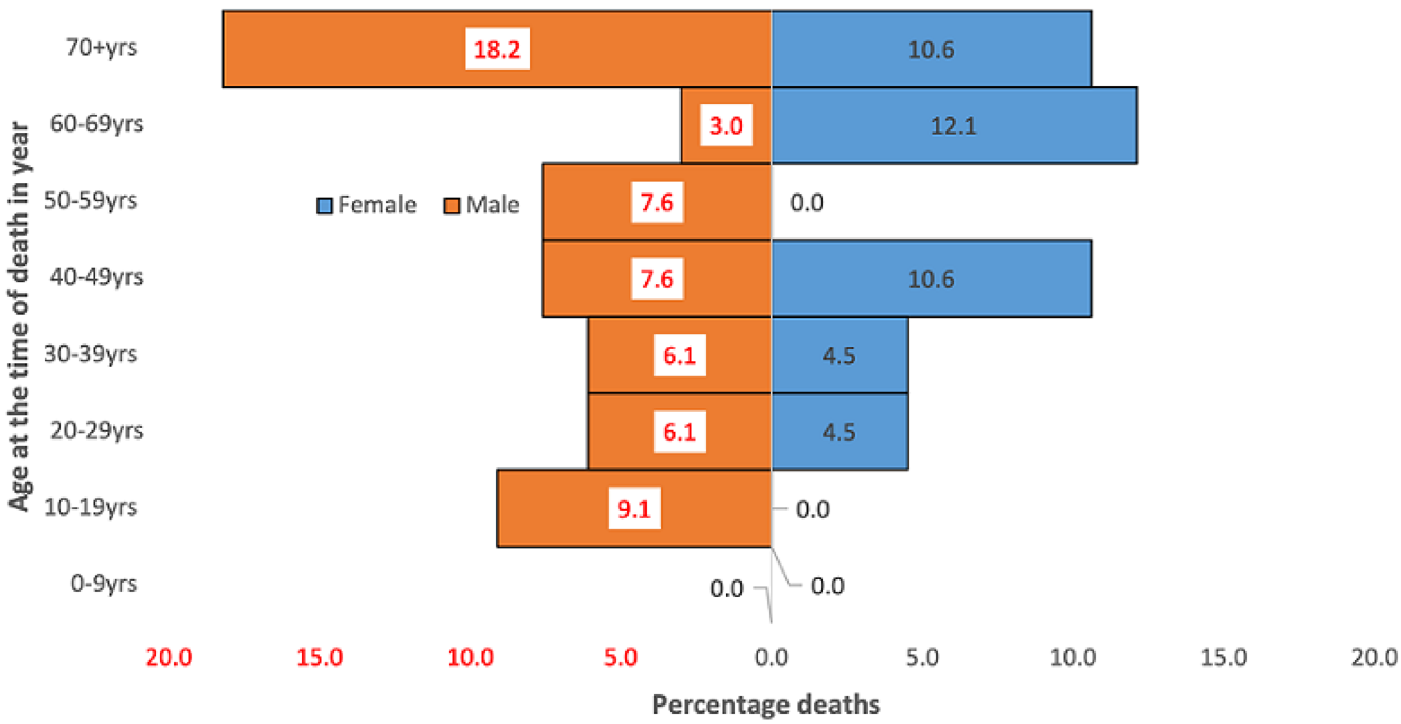

Figure 4: COVID-19 deaths in Bentiu IDP camp, Unity state, 2 May 2020 to 7 November 2021

Table 3: crude and under five mortality rates in Bentiu IDP for 2019, 2020, and Nov 7 2021

Year	<5 yrs	≥5 years	Total deaths	Mid-year�population	Number of weeks	U5MR/10,000/day	CMR/10,000 /day
2019	197	347	544	100,441	52	0.27	0.15
2020	196	321	517	114,330	52	0.24	0.12
2021	201	385	586	107,130	47	0.29	0.17
Total deaths	**594**	**1054**	**1648**				

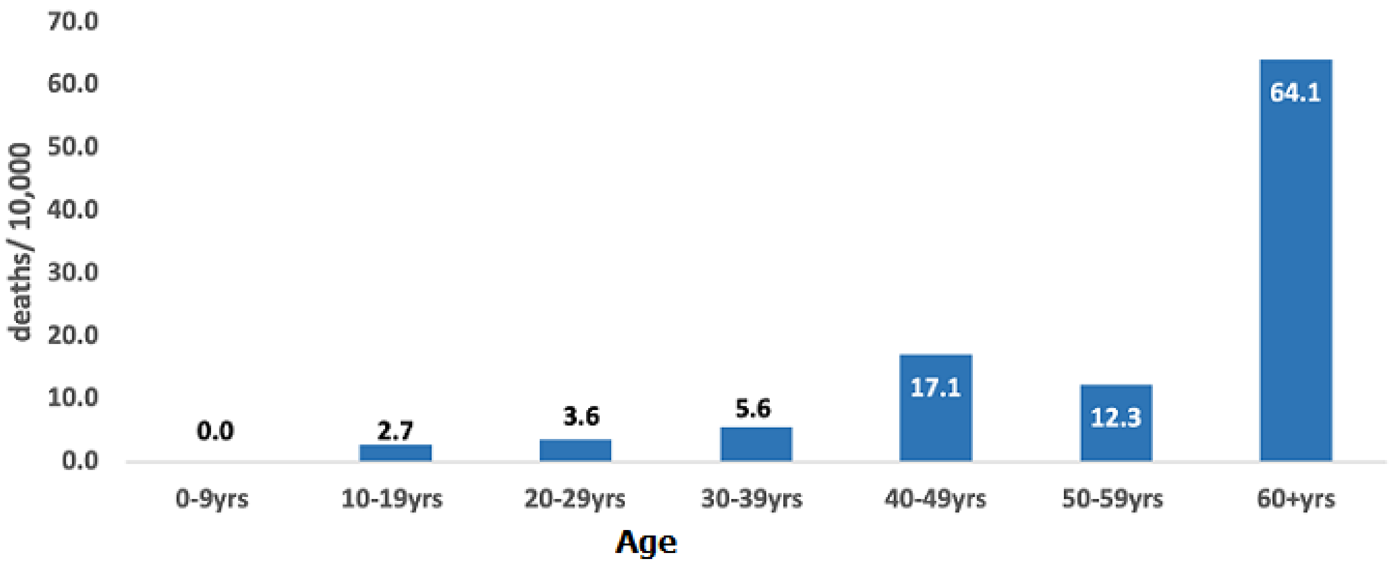

Figure 5: COVID-19 death risk per 10,000 by age, Bentiu IDP, 2 May 2020 - 7 November 2021

Table 4: underlying illnesses in COVID-19 deaths in Bentiu IDP camp, 2 May 2020 - 7 November 2021

S no.	Underlying illnesses	Total deaths	Proportion of deaths
1	Missing	28	42.4%
2	HIV related illness (HRI)	17	25.8%
3	Heart disease	5	7.6%
4	Tuberculosis	3	4.5%
5	Renal disease	3	4.5%
6	Stroke	2	3.0%
7	Anemia	1	1.5%
8	Asthma	1	1.5%
9	Diabetes	1	1.5%
10	Encephalopathy	1	1.5%
11	HBV	1	1.5%
12	Multiple organ failure	1	1.5%
13	Neurosyphilis	1	1.5%
14	Septicemia	1	1.5%
15	Total deaths	66	100.0%

Discussion

The impact of COVID-19 has been unprecedented with even the best health systems struggling to cope with the demand to optimize surveillance through case finding and investigations, contact tracing, testing, and medical care severe and critical care thus justifying the need for population wide restrictions on travel and gatherings [20]. The World Health Organization has proposed critical response actions for a comprehensive whole of society COVID-19 response [14]. In resource constrained settings, where population wide restrictions are likely to have a huge impact on livelihoods, an approach that entails focus on engaging communities to shield the most vulnerable, self-isolation for mild to moderately ill, and moderate distancing in the community has been proposed [15].

In South Sudan, COVID-19 cases were reported in a population that had already braced multiple shocks of a protracted humanitarian crisis with severe food insecurity, disease outbreaks, floods, and displacement rendering the population vulnerable and at risk of devastating COVID-19 outcomes [1]. In this present study, at least 349 COVID-19 cases were reported in Bentiu IDPs. This translates into a cumulative attack rate (cases per million) of 3,230 for Bentiu IDP. This is three times higher than the national attack rate of 1,038 but many times lower than 5,577, the average cumulative attack rate for the African region that varied from 282 in Niger to 228,794 in Seychelles [21]. The COVID-19 CFR in Bentiu IDP was 19.08%, which much higher compared to the national average of 1.06%, the average for the African region [2.5%], and 4.3% in Ethiopia but lower than 59.4% in South Africa [21]. These differences in CFR highlight the elevated vulnerabilities and less than optimal access to COVID-19 interventions including surveillance, testing, case management, and public health social measures. However, the elevated CFR could be explained by low case detection due to low testing rates in South Sudan that stand at 2.3 tests per 10,000 per week and hence leading to undetected cases at community level [8,22].

In terms of COVID-19 trends, COVID-19 cases were not reported in Bentiu IDP until week 18, 2020 and sporadic transmission continued until week 5, 2021 and reaching a peak of 9.1 cases per week in week 6, 2021. This coincided with peak of the second COVID-19 transmission wave in South Sudan and in the African region during which new variants including the eta SARS-CoV-2 variant were detected in South Sudan [23]. The variants detected during the second wave in South Sudan explain in part the more than 200% percent excess transmission registered in comparison to the first wave [23].

Most COVID-19 cases in Bentiu IDP were male (60.7%), a finding that is consistent with gender case distribution at national level and in the African region [8,21]. This is explained in part by better access to testing facilities by men when compared to women, and the better compliance to public health social measures by females when compared to the males. This present study also revealed that young adult males 20-49 years registered most of the cases. A similar distribution was reported at the national level and in the African region with most of these being asymptomatic [8,21]. Hence only 34% of COVID-19 patients in Bentiu IDP were admitted into the isolation facility with most admissions reported in the 60-69 year and ≥70 years age groups who globally, have found to be at a higher risk for severe and critical COVID-19 disease [24]. In the same way, the risk of death from COVID-19 in Bentiu IDP was highest among persons ≥60 years, thus highlighting the need to shield elderly persons in displaced populations [15]. This present study also showed that the most common underlying illnesses reported among COVID-19 deaths in Bentiu IDP were HIV related illness, heart disease, tuberculosis, and stroke. These co-morbidities have been reported to increase the risk of death from COVID-19 and other respiratory illnesses [13,24]. These findings reinforce the need to optimize access to essential healthcare including chronic care in displaced populations to reduce the risk of death from COVID-19.

Given the paucity of the surveillance system in the country and in displaced populations, this present study assessed CMR and U5MR for Bentiu IDP before and during the pandemic. The findings revealed marginal increases with no significant differences in CMR and U5MR in Bentiu IDPs before and during the pandemic. It is therefore unlikely that a significant number of community deaths that could be attributed to COVID-19 occurred and were missed by the surveillance system.

This study had several limitations including the paucity of the COVID-19 surveillance at community and health facility level and the inadequate access to testing in Bentiu IDP camp and the country at large. The stigma associated with COVID-19 also had a negative impact on self-reporting of cases and probable deaths from the communities. These gaps in COVID-19 case and deaths reporting also constrained the identification, and investigation of contacts, as well as investigation and ascertainment of probable COVID-19 deaths in the community. We used the existing integrated disease surveillance and response (IDSR) and Early Warning Alert and Response Network (EWARN) morbidity and mortality data to complement the COVID-19 case and mortality line listing.

Conclusion

COVID-19 had a significant impact on displaced populations of South Sudan with a cumulative attack rate that that was three times higher than the national average. Similarly, the risk of death among COVID-19 cases among displaced populations was high. The COVID-19 case fatality ratio was 19 times higher in displaced populations when compared to national average. There was only one wave of transmission in the displaced populations. This wave lasted at least four weeks from week 5, 2021 and coincided with the second wave of COVID-19 spread in South Sudan. The exponential transmission during this wave was associated with the isolation of eta as the predominant SARS-CoV-2 variant in the country. Adult males aged 20-49 years were the most affected by COVID-19 illness while adults 60 years and above were found to have a higher risk of severe and critical illness as well as death from COVID-19. The commonest underlying illnesses among COVID-19 deaths in displaced populations included HIV related illness, heart disease, tuberculosis, and stroke. There were marginal increases with no significant differences in crude mortality rate and under five mortality rates in displaced populations before and during the COVID-19 pandemic. There is need to optimize COVID-19 response in displaced populations and the high risk groups therein with special emphasis on improving COVID-19 surveillance, testing, contact tracing, case management, vaccination, improving adherence to the public health social measures, and ensuring access to essential health services to treat other causes of morbidity and mortality.

Availability of data and materials: this study used information and data that is available from the South Sudan Ministry of Health Public Health Emergency Operations Center (PHEOC) and generated in support of the ongoing COVID-19 response in the country.

What is known about this topic

- The coronavirus disease 2019 (COVID-19) is a respiratory disease caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) virus with a disease spectrum that spans from asymptomatic, mild, and moderate to severe and critical illness. The majority of the patients in the general population present with asymptomatic or mild disease with the risk of adverse COVID-19 outcomes increasing with advancing age and underlying medical illnesses.

What this study adds

- The study presents the epidemiological characterization of COVID-19 in vulnerable humanitarian populations that are inherently at risk of suffering adverse COVID-19 outcomes. The findings are thus critical for ensuring equity in the distribution of medical countermeasures to avert adverse COVID-19 outcomes.

Competing interests

The authors declare no competing interests.

Authors' contributions

JFW, FL, SJD, KKB, AGG, AM, FN and JPR analyzed the data and prepared the manuscript. All authors read and approved the final manuscript.

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Research

Analysis of the 2017-2018 Rift valley fever outbreak in Yirol East County, South Sudan: a one health perspective

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Abstract

Introduction: the emergence and re-emergence of zoonotic diseases have threatened both human and animal health globally since their identification in the 20th century. Rift Valley fever (RVF) virus is a recurrent zoonotic disease in South Sudan, with the earliest RVF cases confirmed in 2007 in Kapoeta North County, Eastern Equatoria state.

Methods: we analyzed national RVF outbreak data to describe the epidemiological pattern of the RVF outbreak in Yirol East county in Lakes State. The line list of cases (confirmed, probable, suspected, and non-cases) was used to describe the pattern and risk factors associated with the outbreak. The animal and human blood samples were tested using Enzyme-Linked Immunosorbent Assay (ELISA) (Immunoglobulin IgG and IgM) and Reverse Transcriptase-Polymerase Chain Reaction (RT-PCR). Qualitative data were collected from weekly RVF situation reports, and national guidelines and policies.

Results: between December 2017 and December 2018, 58 suspected human RVF cases were reported. The cases were reclassified based on laboratory and investigations results, such that as of 16th December 2018, there were a total of six (10.3%) laboratory-confirmed, three (5.2%) probable, one (1.7%) suspected, and 48 (82.8%) non-cases were reported. A total of four deaths were reported during the outbreak (case fatality rate (CFR) 6.8% (4/58). A total of 28 samples were collected from animals; of these, six tested positives for RVF (positivity rate of 32.1% (9/28). The outbreak was announced in March 2018, after four months of the first reported suspected RVF case. Several factors were attributed to the delayed notification and outbreak announcement such as lack of multi-sectorial coordination at the state and county level, multi-sectoral coordination at national level mostly attended by public health experts from human health, inadequate animal health surveillance, poor coordination between livestock disease surveillance and public health surveillance, limited in-country laboratory diagnostic capacity, the laboratory results for the animal health took longer than expected,, and lack of a national One Health approach strategy.

Conclusion: the outbreak demonstrated gaps to investigate and respond to zoonotic disease outbreaks in South Sudan.

Introduction

There has been an increased global interest in emerging zoonotic diseases [1]. Zoonotic diseases are: "any diseases or infections that are naturally transmissible from vertebrate animals to humans" [1]. There are over 200 known types of zoonoses; they comprise a large proportion of existing and new diseases in humans [1]. Rift Valley fever (RVF) is one such zoonotic disease that is caused by the Rift valley fever virus (RVFV) [2]. Rift valley fever virus is in the Phlebovirus genus, order of Bunyavirales, family Phenuiviridae first identified in 1931 [3]. Rift valley fever virus is an acute arthropod-borne viral disease that primarily affects wild and domestic ruminants including cattle, goats, sheep, buffalos, and camels and humans. Infection can cause severe diseases in both animals and humans and because of long inter epi-zoonotic intervals is referred to as a re-emerging disease. Most human infections result from direct or indirect contact with the organs or blood of infected animals [4]. The virus can be transmitted to humans by handling animal tissue during slaughtering or butchering, assisting with animal births, conducting veterinary procedures, or from the disposal of carcasses or fetuses [5]. Human infection also occurs from the bites of infected mosquitos, most commonly Aedes, Anopheles and Culex species, and transmission through blood-feeding flies; however, there are no reported cases of human-to-human transmission to date [5]. Rift valley fever virus causes a storm of abortions in domestic and wild pregnant animals and excess mortality among young animals [6-8]. The disease in humans causes severe forms of "influenza-like" infection characterized by headache, fever, vomiting, weight loss, and muscle pain with a mortality rate of <2% [9,10].

Since the first outbreak was detected among sheep in a farm in the Rift valley farm of Kenya in 1931, several outbreaks have been reported in sub-Saharan Africa, including Sudan [5]. In 2000, the virus spread outside of Africa, with the first case of RVF reported in Yemen and Saudi Arabia following infected livestock trade from Africa. This had raised concerns that the disease could extend to Europe and other parts of Asia [11]. As a result, there was a disruption of livestock trade between countries. Between 2006 and 2007, there was a 60 million US dollar economic loss experienced by East Africa countries due to the disruption of livestock trading [12]. Rift valley fever outbreak is a recurrent zoonotic disease in South Sudan. The outbreaks of RVF occurred in White Nile State (in Sudan) in 2007. This area borders the Upper Nile of South Sudan. A total of 747 confirmed human cases including 230 deaths (case fatality 30.8%) were reported, although it has been estimated 75,000 were infected [13,14]. During the 2007 RVF outbreak in Sudan, two suspect RVF deaths were reported from Renk and Jouda in South Sudan with heavy flooding in the whole of Upper Nile [13,15]. During the same year (2007) a suspect RVF human case was reported from Kapoeta North County and a follow-up animal serosurvey showed a prevalence of 0.9% for RVF IgM [16,17]. This study describes the epidemiology of the RVF outbreak in Yirol East County, South Sudan and presents the information generated during this outbreak. The study objectives are fourfold: first to understand the epidemiology of RVF outbreak that occurred between 2017-2018; second to examine the country´s laboratory capacity to test RVF; third to identify barriers to application of the One Health approach in investigating zoonosis; and fourth to develop recommendations to strengthen One Health approach n South Sudan.

Methods

Study setting: the Republic of South Sudan is the youngest country in Africa, with a landmass of 619,745 km^2 with an estimated population of 11.4 million [18]. The country is bordered by the Democratic Republic of Congo (DRC) and Uganda in the South, the Central Africa Republic in the West, Sudan in the North, Ethiopia in the East, and Kenya in the Southeast. It is subdivided into 10 States, three special administrative areas, and 80 administrative Counties [19]. Yirol East and livelihoods. The three main economic activities in Yirol East County are cattle keeping, the county is located 418 kilometers northwest of the capital Juba, in Lakes state in central South Sudan. The population estimate of the county was over 100, 000 based on a 2008 population census. The county is surrounded by lakes and rivers, which supply water for humans, livestock, and wildlife. Fish from these water bodies contribute a large part to the communities´ diet in fishing, and cultivation of crops. The outbreak primarily affected the Payams of Yali (particularly Wunthou Boma (also called Thonabutkok Village) and Pagarau. In the county, rainfall and flooding before the outbreak created pools of stagnant water, potentially enabling transovarially infected mosquito eggs (known to survive long periods on the soil surface) to hatch and amplify [20]. The surface water provided a breeding ground for the amplification of the arthropod vectors in an area hosting a large number of cattle communities. These Payams are within proximity to larger water bodies, including the White Nile, Wunthou River and Lake Yirol that serve as common water sources for humans, wild and domesticated livestock.

The surveillance system for RVF in South Sudan: the South Sudan disease surveillance uses the Integrated Disease Surveillance and Response (IDSR) and Early Warning and Response Network (EWARN). The IDSR strategy is designed to capture various diseases, including diseases of outbreak potential. RVF is one of the epidemic-prone diseases stated under the national IDSR Technical Guideline (2013). Accordingly, during the 2017/2018 RVF outbreak, the case definition in the National IDSR Technical guidelines was used for the field investigation. The guidelines define a suscpected RVF case depending on whether it is early or late presentation. The criteria include: *early disease:* acute febrile illness (axillary temperature >37.5°C or oral temperature of >38.0°C) of more than 48 hours duration that does not respond to antibiotics or antimalarial therapy, and is associated with: direct contact with sick or dead animal or its products AND/OR; recent travel (during last week) to, or living in an area where, after heavy rains, livestock die or abort, and where RVF virus activity is suspected/confirmed AND/OR; abrupt onset of any 1 or more of the following: exhaustion, backache, muscle pains, headache (often severe), discomfort when exposed to light, and nausea/vomiting AND/OR; nausea/vomiting, diarrhoea, or abdominal pain with 1 or more of the following: severe pallor: low platelets (thrombocytopenia) as evidence by the presence of small skin and mucous membrane hemorrhages. AND/OR: evidence of bleeding into the skin, bleeding from puncture wounds, from mucous membranes or nose, from the gastrointestinal tract and unnatural bleeding from the vagina AND/OR: clinical jaundice. *Late stages of diseases or complications (2-3 weeks after onset):* Patient who have experienced, in the preceding months a flu-like illness, with clinical criteria, who additionally develop the following: CNS manifestations which resemble meningoencephalitis AND/OR; unexplained visual loss OR; unexplained death following the sudden onset of acute flu-like illness with hemorrhage, meningoencephalitis, or visual loss during the preceding month. The guidelines incorporated several RVF surveillance tools for use in the health facility and community. The tools are case definition, alert identification, and blood sample collection, storage, and transportation procedures. Further, the country surveillance system incorporated an Early Warning Alert and Response System (EWARS); the system is designed to automatically flag alerts daily or weekly, inform surveillance officers and relevant authorities to verify and investigate the alert without delay.

Outbreak detection and investigation: in the epidemiological week 52 of 2017, the State Ministry of Health was notified of a cluster of deaths in the Thonabutkok village of Yali Payam. Three deceased persons were reported to have presented with hemorrhagic symptoms. A multidisciplinary national Rapid Response Team (RRT) was dispatched to support the state in conducting investigations. The team conducted interviews with the affected families, took verbal autopsies using the WHO standard tool and collected both human and animal blood samples [21]. The team witnessed zoonotic events such as abortion among sheep and goats, as well as carcasses of domestic animals that had recently died. Besides, the finding from the field investigation revealed that abortions in small animals (goats and sheep) occurred two months before human cases [22].

Sample collection and testing procedure: five milliliters of blood were collected from all patients with symptoms compatible with the suspect case definition. These samples were transported by road to Rumbek town, flown to Juba, and then to the Uganda Virus Research Institute (UVRI). Samples were tested for the common viral hemorrhagic fevers (i.e. Ebola, Marburg, Crimean Congo Hemorrhagic Fever (CCHF), yellow fever, and Sosuga virus) using reverse transcriptase-polymerase chain reaction (RT-PCR). Additionally, antibody tests using enzyme-linked immunosorbent assay (ELISA) were conducted. The ELISA tests confirm infection with the RVFV by showing the presence of IgM antibodies, which appear briefly to show an acute infection, and or IgG antibodies, which appear for an extended period. Both IgM and IgG antibodies are specific to the RVFV infection [23]. A confirmed case was defined as detecting Ribonucleic Acid (RNA) amplification, or IgM and IgG against RVF in both animal and human blood samples [23]. Twenty-eight livestock samples were also collected and transferred to Juba. The samples were shipped to the United Nations Food and Agricultural Organization (FAO) collaborating laboratory centre in South Africa and Uganda Viral Research Institute (UVRI) in Uganda.

Data collection and analyses: the quantitative data were collected from an Excel based RVF line list. All the 58 RVF suspected cases listed in the line list were included for the quantitative study. For qualitative data we have used weekly RVF situational report, weekly Integrated Disease Surveillance and Response (IDSR) report, South Sudan Joint External Evaluation (JEE) of core capacity for International Health Regulation (IHR 2005) report, Joint Risk Assessment (JAR) report, publication at WHO websites, National Action Plan for Health Security (NAPHS), and East Africa Regional One Health Strategy [24-27]. Ministry of Health (MoH) granted access for the use of a line list for publication. We reviewed, cleaned, incorporated, and conducted a descriptive analysis of the Excel-based line list using IBM Statistical Package for Social Science Version 26.0 (IBM SPSS 26). For categorical variables like gender, patient outcome, symptoms, and risk factors (i.e. exposure to sick or dead animals, animal products, and proximity to places where abortions among domestic animals occurred). We obtained the mean, median, mode, and standard deviation for a continuous variable like age. We tabulated risk factors by case classification (i.e. negative and positive) in the bivariate analysis. Furthermore, we conducted Pearson´s chi-squared test using two-by-two table tests to determine the association between a risk factor and RVF case classification. The level of association was measured at a $P<0.05$ level of significance. For the qualitative review of the study, we used the van Wijnagaarden et al. strengths, weaknesses, opportunities, and threats analysis method [28]. We extrapolated, compiled, and reviewed information, which was related to outbreak response coordination, disease surveillance at human-animal ecosystem interface, integrated animal-human early warning, alert and response system (EWARS), national public health and veterinary laboratory diagnostic capacity. Besides, the review was made on the application of a multi-sectoral One Health approach from the available documents. We grouped the information into available systems and resources (strengths and weaknesses) and contextual factors, and stakeholder analysis (opportunities and threats).

Ethical consideration: administrative clearance for publication of this editorial was provided by the Ministry of Health of South Sudan and WHO (WHO e-Pub no: ePub-IP-00331583-EC) to publish the result. Confidentiality was ensured as the line list was anonymized, and data protection measures were employed to ensure the security of the data.

Results

From December 2017 to December 2018, 58 suspected human RVF cases were reported and investigated by the rapid response teams (Figure 1). A total of four deaths were reported during the outbreak (case fatality rate (CFR) 40% (four deaths out of 10 cases (4/10)). The calculated attack rate was 55 cases per 100,000 population of Yirol East county from the population projection of Yirol East county was 102,158 in 2017. The males and females were equally affected (50%). The median age of the confirmed cases was 27 (Table 1). Four out of six (66.7%) confirmed cases had exposure to abortion or dead young domestic animal within the homestead (Table 1). During the field investigation of a total of three livestock were sick, of these two abortions were observed (one in goat, and one in sheep) and one bleeding in cattle. Two deaths were recorded in animals (one goat with tissue bleeding and one wide bird death)). A total of 28 domestic animal blood samples were tested for RVF antibody; of these 9 (32.1%) were tested positive. Out of 28 animal samples, nine were positive for RVFV antibody using ELISA (three were positive for IgM and six were positive for IgG). Of the total animal sample, 13 were

Table 1: socio-demographic characteristics and epidemiological distribution of RVF in South Sudan-December 2017 to December 2018

Variable	Category	Confirmed cases (6) (%)	Probable cases (n=3) (%)	Suspected cases (n=16) (%)
Patient outcome	Alive	6(100%)	0(0.0%)	14(87.5%)
	Died	0(0.0%)	3(100.0%)	2(12.5%)
	Median	27	15	11
Gender	Female	3(50.0%)	2(66.7%)	38(50.7%)
	Male	3(50.0%)	1(33.3%)	37(49.3%)
Exposure to sick or dead animal	Yes	1(16.7%)	2(66.7%)	13(81.2%)
	No	5(83.3%)	1(33.3%)	3(18.7%)
Proximity to abortion or dead young domestic animals in homestead	Yes	4(66.7%)	1(33.3%)	13(81.2%)
	No	2(33.3%)	2(66.7%)	3(18.7%)

Table 2: summary of laboratory investigations, rift valley outbreak, South Sudan-December 2017-December 2018

Samples shipped to WHO/FAO collaborating laboratories	Number
Human	55
Livestock	28
Total samples (both human and livestock)	83
Human samples - PCR negative for Ebola, Marburg, CCHF, and RVF	48
Human samples - RVF serology - IgM and IgG positive (high titers)	1
Human samples - RVF serology - IgG positive (high titers)	5
Human sample-RVF serology-Not known	1
Total human sample	55
Livestock samples - RVF serology - IgM positive	3
Livestock samples - RVF serology - IgG positive	6
Livestock sample-RVF serology negative (both IgM and IgG)	19
Total livestock sample	28

Table 3: list of symptoms among RFV cases, South Sudan-December 2017 to December 2018		
Symptoms	**Confirmed RVF (n=6)**	**Probable cases (n=3)**
Bleeding	3(50.0%)	3(100.0%)
Breast pain	1(16.6%)	0(0.0%)
Chest pain	1(16.6%)	0(0%)
Convulsion	0(0.0%)	1(33.3%)
Cough	1(16.6%)	0(0.0%)
Dyspnoea	1(16.6%)	0(0%)
Fever	5(83.3%)	3(100.0%)
Headache	5(83.3%)	3(100.0%)
Joint pain	4(66.6%)	3(100.0%)
Muscle pain	2(33.3%)	3(100.0%)
Pain behind the eye	1(16.6%)	0(0.0%)
Sore throat	6(100%)	3(100.0%)
Vomiting	0(0.0%)	0(0.0%)

Table 4: (SWOT) analysis of Rift valley fever outbreak response, South Sudan-December 2017 and December to April 2018				
Domain	**Strengths**	**Weakness**	**Opportunities**	**Threats**
Outbreak response coordination	1. Public health emergency operation center function to coordinate public health emergency response.	1. Weak public health coordination at the state level.	1. Availability of state ministry of health structures and leadership, and state health partners (non-governmental and UN Organizations).	1. The development of the national One Health approach strategy was not finalized, i.e. still at the draft stage.
	2. Trained multi-disciplinary rapid response team are available at the national state level	2. Take four months (December 2017 to March 2018) to declare an outbreak of RVF.	2. Availability of trained rapid response Team in 10 states of South Sudan.	2. Lack of multi-sectorial coordination at the state and county level.
				3. Multi-sectoral coordination at national level mostly attended by public health experts from human health,
				4. Bad roads network and insecurity that hinders deployment of outbreak investigation and response team.
Disease surveillance at animal-human ecosystem interface	1. The South Sudan national IDSR guideline listed RVF as one of reportable diseases.	1. Delayed detection, notification and confirmation of RVF cases (index case date of onset was 7th December, notification 28th December, confirmation on the 3rd January 2018).	1. Availability of the IDSR guideline and surveillance tools.	1. Shortage of human and financial resources.
	2. Surveillance tools such as case definitions, and reporting formats were printed and distributed.	2. Failure to detect and notify livestock deaths prior to first human cases.	2. Existence of early warning, alert and response system (EWARS).	2. High turnover of trained health workers.
			3. Existence animal and human health implementing partners.	3. Weak collaboration among stakeholders at national and state level.
National diagnostic laboratory	1. There are functional national public health laboratory and central veterinary diagnostic laboratory.	2. Lack of reagents to confirm animal and human samples.	1. The National Public Health Laboratory has RT-PCR machine to confirm a number of viral hemorrhagic disease such as Ebola, Marburg, Yellow Fever, CCHF and RVF.	1. Lack of interest of donors and financial institute to support the laboratories.
		3. Lack of resources such as trained manpower, finance and supplies.	2. Existence of partners including the UN organizations.	2. Lack of motivation packages and salary to retain trained manpower at public health and veterinary laboratories.
				3. The laboratory results for the animal health took longer than expected
One Health approach	1. Incorporation of One Health approach into the South Sudan National Action Plan for Health Security (NAPHS) 2020-2024	3. Lack of clearly developed national One Health approach strategy.	5. Existence of partners at national and state level.	1. Both government and partners high staff turnover
	2. Joint risk assessment (JRA) was conducted for the prioritization of Zoonotic diseases	4. Irregular or no coordination among One Health approach implementing partners.		
			6. The IDSR guidelines prioritized a number of zoonotic disease for surveillance.	

negative for RVFV antibody (non-cases) and six were classified as a suspected case (the results were not known) (Table 2). The cases were reclassified based on laboratory and investigations results, such that as of 16th December 2018, there were a total of six (10.3%) laboratory-confirmed (one case was positive for both IgG + IgM, and five cases were positive for IgG). Three (5.2%) probable (samples were not collected), one (1.7%) suspected (result was not known), and 48 (82.8%) non-cases (negative for both IgM and IgG) were reported (Table 2).

The most frequent symptoms among the suspect, probable, and confirmed human cases were bleeding, fever, headache, joint pain, and muscle pain. Bleeding such as nasal bleeding, gum bleeding and petechial rash were reported in all suspected and probable cases. Three out of six (50%) confirmed cases had bleeding manifestation (Table 3). The main risk factors included in the line list were exposure to morbid or dead animals and proximity to animals that had an abortion or young domestic animals that died. Cases (confirmed, probable, and suspected) cases have 1.3 times has a higher risk of exposure than none cases. There was no significant difference in exposure to the sick or dead animal among RVF cases (confirmed, suspected, and probable) than non-RVF cases (P=0.68). The identified threats were lack of the availability of human and financial resources, challenging access to the communities, and political insecurity. During the RVF outbreak, the identified strengths included the existence of multi-sectorial outbreak coordination at the national level; availability of trained multi-disciplinary Rapid Response Teams (RRTs); the existence of national disease surveillance guidelines; availability of surveillance tools such as case definition; joint risk assessment and zoonotic disease prioritization; functional National Public Health Laboratory (NPHL) and Central Veterinary Diagnostic Laboratory (CVDL); and, the existence of partners institutes and organizations for multi-sectoral coordination. The weaknesses identified during the study were delayed case detection and notification, delayed outbreak announcement, lack of veterinary services, the weak linkage between animal and human disease surveillance systems, lack of clinical history taking and diagnostic capacity, shortage of laboratory reagents, and poor understanding and application of multi-sectoral one health coordination. The opportunities were the existence of a functional state ministry of health and state partners (non-Governmental and UN Organizations) for multi-sectorial coordination; the existence of the Early Warning, Alert and Response System (EWARS); the existence of the NPHL and CVDL molecular testing centre; and the existence of the Public Health Operation Center (PHEOC) for all public health hazard coordination (Table 4).

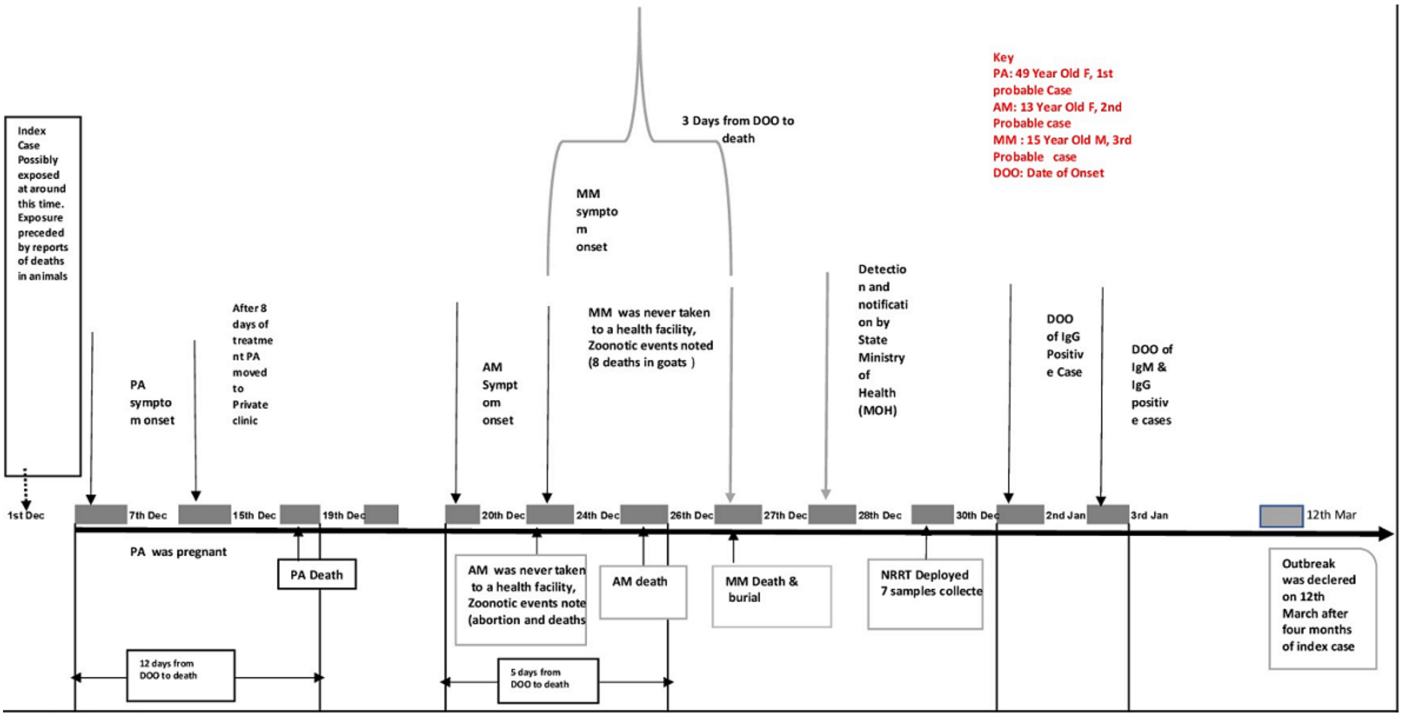

Figure 1: timeline of the Rift Valley Fever Outbreak, Yirol East county, South Sudan- December 2017 to April 2018

Discussion

The 2017 to 2018 outbreak in Yirol East County is the first major recorded RVF outbreak in South Sudan. From December 2017 and May 2018, South Sudan reported 25 human RVF cases. A total of five deaths were reported during the outbreak (case fatality rate (CFR) 20.0%). However, before the independence in 2011, South Sudan, as part of the White Nile Region of Sudan, experienced RVF outbreaks in 1973, 2007, and 2010. Therefore, there is a high possibility of cross-border circulation of the virus due to livestock movement, livestock trade, climate variability, and epizootic sweeping to South Sudan [13, 14]. Rift valley fever is mostly suspected when human cases appear which is not the ideal situation as outbreaks occur first in the animal population which should serve as an early warning for the human outbreak. In this outbreak, in the absence of veterinary services and lack of coordination between the veterinary and human public health sectors, the detection of human cases was delayed. The Yirol East County, South Sudan outbreak was detected in a dry season of 2017, 2018, yet RVF outbreaks largely follow flooding [29]. This is not the usual encounter, as it was noted by Hassan et al. (2011) [13]. Nevertheless, Payams of Yali and Pagarau in Yirol East county are surrounded by lakes and rivers which supply water for humans, livestock, and wildlife. This coupled with the wetland pools and stagnant water created by rainfall, established a favourable ground for mosquito breeding [30,31]. Besides, the area is typical of cattle keeping communities in South Sudan; where large swaths of designated cattle camps where young men tend to herd cattle moving around with the animals searching for pasture and drinking water. Hence, flooding in the geographic area with high-density wildlife and livestock created a favorable environment for RVFV transmission [32,33].

Rift valley fever outbreak is mostly suspected when human cases appear, which is not the ideal situation as outbreaks occur first in the animal population which should serve as an early warning for human outbreak [34]. In this outbreak, in the absence of veterinary services and weak coordination between the veterinary and human public health sectors, the detection of human cases was delayed by two months [22]. In the reported human cases, the epidemiological profile and clinical pattern of the cases were like what has been seen in other outbreaks [33,35]. The most common symptoms were fever and headache. As seen in the 2012 Mauritania RVF outbreak, the hemorrhagic manifestation was quite common (90%) in this outbreak, though most were epistaxis and bleeding of gums [36,38]. The case fatality ratio (CFR) of 20% is higher than the 1% CFR threshold, but similar findings of increased CFR were reported in Madagascar (3%) and Mauritania (50%) [37,38]. The high CFR is probably related to the underestimation of RVF cases due to the weak health system, weak community and health facility surveillance, lack of capacity to diagnose RVF, and poor health-seeking behavior. We saw an increased exposure to carcasses and raw milk consumption; 40.7% of cases reported exposure to the risk factors in our study. A study in South Africa revealed that 89% of confirmed RVF cases have contact with animal blood, tissues, or other body fluids [36]. Furthermore, the finding of our study is consistent with the findings in Tanzania's and Kenya´s RVF outbreaks in 2007, whereby 40% of cases reported contact with sick animals and carcasses [3,9,10]. The finding entails focused risk assessment and risk communication interventions at the national and sub-national levels [25]. Rift Valley fever is one of the reportable zoonotic diseases; the Integrated Disease Surveillance and Response (IDSR) guidelines enable the national, state, and county health authorities to report immediately if RVF is suspected at the health facility and community level [39]. The guidelines incorporated tools, including RVF case definitions and reporting tools. A standard RVF case definition and other surveillance tools were used during the outbreak investigation [40]. However, surveillance systems and links at the animal-human ecosystem interface remained weak [22]. The situation was compounded by the weak health system, lack of human and financial resources, humanitarian situation, lack of coordination and leadership at various levels. Nevertheless, there are still capacities and success stories in South Sudan that will improve the RVF surveillance system; this includes s the decentralization of the IDSR/EWARS system and prioritization of zoonotic disease through joint risk assessment. Besides, there is an improved capacity at the NPHL to test for Ebola virus disease (EVD), RVF, Yellow Fever, Influenza virus, Marburg, and Coronavirus [41] using RT-PCR molecular diagnostic technique. The existence of partners such as FAO, Ministry of Livestock and Fishery and other partners will improve the multi-sectoral coordination of the One Health approach.

A total of 31 human blood sample and 28 animal blood sample was tested using ELISA and RT-PCR for RVF. There was a significant delay of confirmation of the outbreak, the reasons being delayed transportation of samples to reference laboratory and lack of laboratory capacity within the country. In 2019, South Sudan was able to test for RVF using RT-PCR as part of EVD preparedness but there is a strong need to increase the capacity of testing, especially the ELISA test to know the current and previous RVF infection [27]. Moreover, there is a need to establish a functional veterinary sector in the country for animal outbreak investigations and testing capacities. Furthermore, the deferential test for EVD, Marburg, CCHF, Yellow Fever yielded negative results, which is standard practice to exclude other differentials of disease presenting with a hemorrhagic clinical presentation [28]. A multi-sectoral task force established the outbreak response coordination. The task force was represented by the Ministry of Health, Ministry of Wildlife, Environment, Livestock and Fishery, and Defense. These were supported by partners including United Nations Children Fund (UNICEF), WHO, FAO, World Organization for Animal Health (OIE), Medicine Sans Frontier (MSF), European Union Humanitarian Aid, United States Agency for International Development (USAID), and health cluster partners. Though, the outbreak response plan was multi-sectoral certain aspects of the plan, such as the disease control at the animal-human interface, animal and entomological surveillance, was never funded and thus not implemented. Moreover, the community did not appreciate the lack of attention to animal health. During active case searches, the communities regularly asked why much attention was devoted to looking for sick persons, yet their domestic animals were dying every day, and nothing was being done for them. Often, the animal and the environmental component of one health are neglected or underfunded; hence, equitable inclusion of all component are very essential to fulfill the definitions of one health approach [42]. Furthermore, the absence of skilled veterinary personnel at the subnational level made it hard to constitute multidisciplinary teams to conduct active searches. To a community that highly values their cattle and other domestic animals, this was a "half measure response to their plight". It has been demonstrated that the One Health approach can result in improved zoonotic disease surveillance at the animal-human-ecological interface; though, the implementation of the approach requires context analysis, political commitment, institutional and financial capacity [43].

Conclusion

The outbreak imposed a challenge to both animal and public health in South Sudan. In addition to human losses, a significant loss of livestock was reported. From the study findings, it is evident that South Sudan lacks the basic capacity to respond to zoonotic disease outbreaks at the national and sub-national levels. There was delayed notification and investigation of the outbreak, delayed testing and result communication, and a lack of national capacity to confirm RVF. These were compounded by a lack of knowledge on the geographic distribution of RVF in the country. However, the outbreak was an important avenue to record challenges, gaps, and lessons to improve disease surveillance at the human-animal-environment interface, improve disease prevention and control, build testing capacity, and improve collaboration and partnership. We have drawn practical recommendations critical to improving RVF prevention and control in South Sudan. The recommendations include: improve zoonotic disease detection and reporting through enhanced disease surveillance and laboratory capacity; draw lessons from other countries´ experiences to establish efficient RVF control and prevention strategy; establish multi-sectoral One Health platform; and undertake a seroprevalence study in human and animal covering the wide geographic area.

What is known about this topic

- Rift Valley fever (RVF) is one such zoonotic disease that is endemic in parts of Africa and is known to infect a diverse group of animals, including cattle, goats, sheep, buffalos, camels, and others most human infections result from direct or indirect contact with the organs or blood of infected animals. The virus can be transmitted to humans by handling animal tissue during slaughtering or butchering, assisting with animal births, conducting veterinary procedures, or the disposal of carcasses or fetuses;
- Certain occupational groups such as herders, farmers, slaughterhouse workers, and veterinarians are at higher risk of infection;
- One Health approach (multi-sectoral) is required to contain RVF outbreaks and mitigate their impacts.

What this study adds

- In the absence of strong surveillance systems in the animal health sector, most zoonoses are only detected and confirmed when they cross to humans. However, for cattle keeping communities like in South Sudan, a response that is entirely focused on human health does not meet the needs of the community that continue to suffer economic losses;
- In malaria-endemic countries; syndromic malaria surveillance and symptomatic treatment of malaria cases can mask an RVF outbreak, especially during the malaria peak seasons (rainy season in South Sudan). Laboratory confirmation of malaria cases is critical, and multiple cases of fever with negative malaria tests can allow testing for other causes of fever such as RVF and Dengue;
- South Sudan lacks the basic capacity to investigate and respond to Rift Valley fever outbreaks. There is no one health policy, strategy or mechanism established to handle health events at the human-animal-environmental interface.

Competing interests

The authors declare no competing interests.

Authors' contributions

OR, KKB and OOO conceived and designed the article: collection, analysis, and interpretation of data: OR, KKB, JW, IAL and JLKJ. All authors had full access to all the data in the study. KKB as the corresponding author had final responsibility for the decision to submit for publication. The final version of the manuscript has been read and approved by all the authors.

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Research

Evaluation of integrated disease surveillance and response (IDSR) and early warning and response network (EWARN) in South Sudan 2021

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Abstract

Introduction: South Sudan has been implementing the Integrated Disease Surveillance and Response (IDSR) strategy since 2006, along with Early Warning and Alert Response and Network (EWARN). The IDSR/EWARN stakeholders commissioned an independent evaluation to establish performance at national, state, county, health facility, and community levels in the first half of 2021.

Methods: the evaluation was conducted between June and September 2021 (during the COVID-19 pandemic) and was based on the World Health Organization (WHO) protocols for monitoring and evaluating communicable disease surveillance and response systems and the guidelines for evaluating EWARN.

Results: integrated disease surveillance and response/early warning and alert response and network indicator data showed improving timeliness and completeness from the beginning of 2021 to week 16 and then a slight depression of timeliness by week 32, while completeness remained high. Event-based surveillance was active at the beginning of 2021 and in week 32. However, there was inadequate sample collection to investigate acute watery diarrhea, bloody diarrhea, and acute jaundice syndrome alerts. Respondents in all cadres had substantial experience working in IDSR/EWARN. All respondents performed the various IDSR/EWARN tasks and duties as expected, but needed more resources and training.

Conclusion: while IDSR/EWARN is performing relatively well, confirmation of priority diseases by the laboratories needs to be strengthened. Health facilities need more regular supervision from the higher levels. Community health workers need more training on IDSR/EWARN. The whole IDSR/EWARN system needs more resources, particularly for communication and transport and to confirm priority diseases. Staff at all levels requested more training in IDSR/EWARN.

Introduction

Beginning in 1998, the Integrated Disease Surveillance and Response (IDSR) has remained the overarching strategy for strengthening and building robust national disease surveillance systems and is the vehicle for attaining the international health regulations (IHR 2005) core capacity requirements in the World Health Organization (WHO) Africa Region [1-3]. South Sudan has been implementing the IDSR strategy since 2006 [2]. South Sudan has experienced several outbreaks over the years and is part of the yellow fever and meningitis belts [4-8]. Integrated disease surveillance and response aims to establish a national disease surveillance system with capacities to detect, report, confirm and effectively respond to high-priority communicable and non-communicable diseases and other events of public health importance. Given the humanitarian context of the country, South Sudan implemented IDSR alongside the Early Warning Alert and Response Network (EWARN) as an adjunct system that supports surveillance and response needs in locations where IDSR was underperforming due to security constraints. By design, EWARN and similar systems focus on rapid notification of epidemic-prone and other emergent public health diseases [9].

Public health surveillance and response systems require regular evaluations to ensure that they are still aligned with their objectives. In recent years, South Sudan and its partners have invested in IDSR and EWARN [10]. There was a comprehensive mid-term evaluation of the IDSR strategy in South Sudan in 2011 [10]. South Sudan adopted and is using the third edition of the IDSR Technical Guidelines in 2019 [11,12]. In late 2020, the stakeholders commissioned an evaluation to establish the status and performance of IDSR/EWARN capacities at the national, state, county, health facility, and community level. The assessment was to determine the surveillance capacities. The capabilities to detect, report, investigate, analyze, prepare, respond, and provide feedback by surveillance and laboratory focal points, rapid response teams, emergency preparedness and response teams, and other stakeholders at all levels were evaluated. The assessment focused on the first half of 2021. The worldwide COVID-19 pandemic coincided with the evaluation period and reduced the planned size [13]. The final objectives of the evaluation were to describe the IDSR and EWARN systems and how they relate and operate in South Sudan and assess the effectiveness and usefulness of IDSR and EWARN to detect, confirm, and respond to diseases, outbreaks, and events of public health importance. We present the approach, results, and recommendations from the IDSR/EWARN evaluation.

Methods

Approach: the evaluation was based on the WHO protocol for monitoring and evaluating communicable disease surveillance and response systems and the guidelines for evaluating early warning alert and response networks [14-16]. The evaluation occurred between June and September 2021.

Evaluation team: the evaluation was conducted by an independent team comprising a team leader based in Atlanta and a team member based in Juba. They were supported by an IT team based in Atlanta. Because of funding and the COVID-19 pandemic, the plans for the local component of the evaluation were scaled back. The evaluation team reported to the Technical Officer for Emergencies in the WHO Juba Office and the Director General, Preventive Health Services, Ministry of Health who provided technical guidance.

Process

Obtaining background information: the evaluation team identified and obtained all critical documents for providing background information and operational context of IDSR and EWARN. These documents were obtained from the Ministry of Health and WHO and were provided in a shareable folder online.

Site selection

Selection of states: for purposes of this evaluation, the country was divided into three Regions- Equatoria, Bahr el Ghazal, and Upper Nile. The assessment was conducted in one State in each of the three Regions of South Sudan: Equatoria - Eastern Equatoria State, Bahr el Ghazal - Northern Bahr el Ghazal State, Upper Nile - Upper Nile State. The final site selection depended on the availability of respondents given the COVID-19 pandemic travel and other restrictions. There were also team size restrictions based on the pandemic and funding considerations.

Tool adaptation and piloting: data collection tools were adapted to the context of the South Sudan health system and IDSR/EWARN systems. After adaptation, they were piloted to ensure they were comprehensive, appropriate, readable, relevant, and understandable. After the piloting, the tools were updated based on the feedback and finalized for conducting the evaluation. The data were presented in three parts: i) Indicator and event-based surveillance data; ii) quantitative data from the evaluation; iii) surveillance attributes of the IDSR/EWARN system. Conclusions were made from each of the analysis parts, and recommendations were made to the stakeholders.

Ethics approval and consent to participate: administrative clearance for publication of this paper was provided by the Ministry of Health of South Sudan and WHO (WHO e-Pub no: ePub-IP-00332847-EC).

Results

Indicator data: at the beginning of 2021, IDSR timeliness ranged from 37% to 95%, most states were below the target (80%), and the average was 66%. Integrated disease surveillance and response completeness ranged from 50% to 100%, most states were above the target, and the average was 87%. During the same period, county-level IDSR timeliness was 34 (42%), while completeness was 53 (66%) [17]. In weeks 15 and 16, both IDSR timeliness and completeness had markedly improved from where they were at the beginning of 2021. The average for timeliness was 91%, up from 66% and for completeness, it was 92%. Country-level completeness in reporting improved from 53 (66%) in week 1 of 2021 to 62 (78%) in week 16 of 2021 [18]. IDSR timeliness in week 32 was 84%, which improved from week 31 but a drop from week 16. Average completeness in week 32 was 90% which was similar to week 16. Country-level timeliness in week 32, 2021 was 60 (75%), representing a decline from week 16, 2021 [19].

Event-based surveillance: a snapshot of event-based surveillance from weeks 1 and 32 showed multiple alerts from several states. The commonest alerts were acute watery diarrhoea (AWD) and malaria, followed by bloody diarrhoea (BD). The number of states reporting AWD alerts increased from five in week 1, 2021 to nine in week 32, 2021, but the number of states collecting samples to investigate AWD alerts reduced from 6 (86%) to no samples collected to investigate AWD alerts in week 32, 2021. The number of states reporting BD alerts increased from five to seven from week 1 to week 32, 2021, but no samples were collected to investigate the cases reported during the period [17,19].

Quantitative data from the questionnaires: a total of 33 participants responded to the various survey questionnaires either in person or via downloadable links. They were 10 surveillance officers, 10 community health workers, five health facility-based respondents, four senior-level county and central personnel, two laboratory-based respondents, and two data managers.

Surveillance officers: ten surveillance officers responded. Their locations were five from Northern Bahr el Ghazal State, two from Upper Nile State, two from Eastern Equatoria State, and one from Western Equatoria State. The surveillance officers had experience with IDSR/EWARN ranging from 3 to 156 months, five had an experience of 18 months or more, and were either state or country surveillance officers. Their primary responsibilities were data review, compilation/aggregation, data entry, and alert/outbreak investigation.

Reporting sites: the surveillance offices had between 11 and 27 sites reporting to them. Seven of the 10 surveillance officers reported difficulty accessing some of their reporting sites. The commonest reasons for lack of access to reporting sites were the lack of transport and communication. A total of 6 of the 10 surveillance officers reported that all their reporting sites functioned without disruptions or closures in the previous 3 months.

Supervision: the surveillance officers used various methods to supervise their reporting sites. The commonest method was facility visits, followed by telephone calls and training workshops. When asked to report on the percentage of reporting sites that the surveillance officers had visited in

Table 1: surveillance attributes of the IDSR/EWARN in South Sudan 2021		
Attribute and indicator	**Assessed/not assessed**	**Evaluator rating Low/medium/high)**
Simplicity		
IDSR/EWARN integration with other systems	Yes	High
Method to collect, manage, enter, analyze and disseminate data	Yes	High
Time spent on maintaining the system		
Amount and type of data collected for each priority disease (e.g. demographics, exposure information, etc)		
System training	Yes	Low
Flexibility		
Process to add/remove health units/partners	Yes	Medium
Retrospective review of how system responded to a new demand such as		
Emerging health events	Yes	High
Changes in case definitions	Yes	High
Variations in funding	Yes	High
Data quality		
Quality control practices		
Critical discussion of data and reports with partners	Yes	Medium
Use of standardized tools and forms	Yes	Medium
Staff who can correctly identify immediately notifiable diseases	Yes	High
Staff who accurately provide case definitions	Yes	High
Staff who accurately provide alert thresholds	Yes	High
Staff who can correctly explain the alert notification procedure	Yes	High
Training		
Current surveillance officers trained in IDSR/EWARN	Yes	Medium
Current IDSR/EWARN health facility staff trained in EWARN	Yes	Low
New IDSR/EWARN health facility staff (hired within the past 6 months) trained in EWARN		
New IDSR/EWARN partners/reporting sources (added within the past 6 months) trained in IDSR/EWARN		
Length of trainings (initial and refresher)	Yes	Medium
Most common/primary training topics	Yes	High
Primary training facilitators		
Supervision and feedback		
Health facilities which received feedback in previous 4 weeks; in previous 8 weeks	Yes	Medium
Health facilities which received supervisory visits in previous 4 weeks; in previous 8 weeks	Yes	High

the previous 4 weeks, the majority, 6/9, reported that they had visited all the reporting sites. The commonest reasons for visiting the sites were regular supervision (7/9), collecting reporting forms (7/9), and providing feedback (6/9).

Review of the weekly reporting form: all surveillance officers reported that they reviewed the weekly reporting form from their reporting sites. The most typical reason for reviewing the form was to look for missing data.

Feedback to reporting sites: the commonest frequency of providing feedback to reporting sites was reported to be weekly. Primarily by visiting the site or telephone contact. All surveillance officers reported that they conduct meetings with their reporting sites and the commonest frequency was monthly. Most meetings occurred in person. The topics that were discussed at the meeting ranged from strengthening practices discussed in all meetings to outbreak investigation and response, which was discussed in 62.5% of meetings.

Meetings with Ministry of Health/WHO Central level staff: a total of 5/9 surveillance officers reported that they had regular meetings with the Ministry of Health or WHO Central level staff. Those who had meetings reported that they were held monthly and mostly in person. The reasons given for the lack of meetings are primarily a lack of funds and other resources for transportation. Those who had meetings reported that progress since the last meeting was the most discussed topic.

Training in IDSR/EWARN: a total of 4/9 reported that they had received training in IDSR/EWARN in the past 12 months. Those who had received that training indicated that WHO and the Ministry of

Table 1 (suite): surveillance attributes of the IDSR/EWARN in South Sudan 2021		
Attribute and indicator	**Assessed/not assessed**	**Evaluator rating (low/medium/high)**
Acceptability		
Barriers to reporting		
Organization/agency/staff willingness to participate		
Perceived strengths and weaknesses of the system	Yes	Medium
Support and feedback to IDSR/EWARN staff	Yes	High
Regular meetings to review EWARN (strengthen practices, discuss progress, feedback, etc)	Yes	High
Internal review of the data		
Responsiveness of the system to suggestions or comments		
Representativeness		
Groups or subgroups not covered by or included in the system	Yes	Medium
Systematic exclusion or barriers to health care access		
Stability		
Functioning tools/equipment and resources for weekly surveillance and outbreak detection and response	Yes	High
Interruptions to reporting and impact on the system	Yes	Low
Costs involved to maintain the system		
Staff turnover		
Time in current position and EWARN-related activities	Yes	High
Uninterrupted weeks with functioning health facilities in the last 6 months	Yes	High
Usefulness		
Perceived usefulness of IDSR/EWARN data and bulletins	Yes	High
Ppublic health action (e.g., control measures implemented) based on data from EWARN	Yes	High
System's ability to meet its objectives	Yes	High
System's ability to help improve clinical, behavioral, social, policy or environmental practices		

Health had provided it and case definitions, outbreak investigation, data analysis, specimen collection, form completion, case management, and preparedness.

Notification of IDSR/EWARN alerts: the surveillance officers reported that they were most notified about alerts through the bulletins and their reporting channels. Six out of the seven who responded to the question indicated that they maintained an outbreak log or register. All responded that they were involved in alert verification; however, only 5/7 reported being involved in an outbreak investigation.

Resources for alert and outbreak investigation: all surveillance officers reported alert forms, registers, and specimen collection tools. The least resource they had was transportation. Among those who responded, all had tally sheets and weekly reporting forms. Less than half had transportation to aid in weekly reporting.

Changes to IDSR/EWARN: surveillance officers indicated that the commonest change to IDSR/EWARN since they had started working on it was adding or removing reporting sites. A total of 4/9 surveillance officers reported that new sites had been added to supervise in the previous 6 months.

Integrated disease surveillance and response bulletins: all surveillance officers reported that they received the weekly bulletins and found them helpful in various ways, especially in monitoring health trends; 4/7 reported that they believe the surveillance bulletins could be modified to make them more useful by enabling them to send them to reporting sites. The surveillance officers indicated that they share the bulletins with various stakeholders (e.g. other surveillance officers, IDSR/EWARN staff at health facilities, and reporting sites) primarily by email.

Challenges with implementing IDSR/EWARN: the surveillance officers reported that they had various challenges in implementing IDSR/EWARN. The commonest was the lack of sufficient training, the lack of funds, and the lack of communication; they also mentioned a lack of commitment from higher authorities (5/7).

Health facilities: responses were obtained from five health facilities from Makal, Lopa/Lafon, Juba, Maban, and Magwi counties. Four of the five were PHCCs the other was a hospital. The populations in their catchment areas ranged from 280,00 to 648,441. Three of the five belonged to the government, and the other two were nongovernment. The respondents had spent a minimum of 9 months working on IDSR/EWARN to a maximum of 141 months. The only source of interruption in their work was staff absenteeism reported by one respondent, and they spend a median of 8 hours per week working on IDSR/EWARN duties. Other reporting tasks as reported by 3/5 included malaria screening and monthly treatment summaries. Their primary responsibilities in IDSR/EWARN were mainly cased detection, alert, and outbreak investigation.

Supervision: respondents who answered the question reported that they received supervision from a higher level, mostly weekly, as indicated below. The supervision was mainly through facility visits. Supervisors came to strengthen practices, review progress, and collect IDSR/EWARN data.

Feedback: respondents reported that they primarily received feedback

Table 2: laboratory attributes of the IDSR/EWARN in South Sudan 2021		
Attribute and indicator	**Assessed/not assessed**	**Evaluator rating (low/medium/high)**
Simplicity		
Priority conditions that can be laboratory-confirmed	Yes	Medium
Method for reporting results of immediately notifiable conditions	Yes	High
Data quality		
Use of standardized forms	Yes	Low
Legibility of laboratory registers		
Completeness of laboratory registers		
Diagnostic tests for which standard operating procedures are available	Yes	High
Diagnostic tests for which quality control is performed	Yes	Medium
Specimen collection		
Specimens received with a label, with a unique identifier		
Specimens received with adequate material for testing		
Specimens received in the recommended container, including packaging and temperature	Yes	Medium
Specimens received with associated specimen form		
Specimens with date and place of specimen collection on the form		
Specimens with all other data entries on the form completed		
Specimens with receipt time at laboratory recorded	Yes	High
Timeliness		
Samples expected to be analyzed within 24 hours, within 48 hours	Yes	High
Time from specimen arrival at the laboratory to results from the referral laboratory		
Time from specimen collection to arrival in the laboratory	Yes	High
Time from specimen arrival at the laboratory to testing	Yes	High
Time from testing until result reported to the collection site	Yes	Medium
Time from specimen collection until results reported.	Yes	Medium
Stability		
Staff reporting resources for specimen storage and diagnostic testing	Yes	Low

weekly on the data collected on IDSR/EWARN, primarily by facility visits.

Meetings with local staff: strengthening practices was the most frequently mentioned topic that is discussed at meetings with local staff at the health facility level. Three out of four respondents reported that they trained local staff sporadically. The training at the health facilities comprised case definitions, data analysis, specimen collection, and form completion primarily.

Immediate reporting: facility respondents were asked to indicate conditions that required immediate reporting. Acute bloody diarrhoea was not identified as a condition that required immediate reporting by half of the respondents. The respondents were also split on malaria.

Alert notification and outbreak investigation: one of the four health facility respondents reported being involved in outbreak investigations. Three of the four respondents reported they had an outbreak log; however, two only reported a method to update the cases in their registers with laboratory results. Not all the health facility respondents had all the resources needed for outbreak investigation and response. Two of the three had alert forms and registers, and specimen collection tools.

Feedback: all health facility respondents reported that they had not received any weekly bulletins but indicated that the bulletins would be useful if they were receiving them.

Utility of IDSR: all respondents indicated that IDSR/EWARN is useful for monitoring health trends, detecting early outbreaks, and sharing information with partners. They all had used IDSR to respond to outbreaks in their catchment area.

Challenges in IDSR/EWARN: all those who responded indicated that insufficient training was the most challenging part of IDSR/EWARN.

Community health workers: ten community health workers responded to the community health worker questionnaire. They were primarily based at the Payam level. They indicated that they mainly visited their communities weekly. Six out of 10 respondents stated that they were familiar with IDSR/EWARN.

Frequency of visiting communities by community health workers: a total of 7 of 9 respondents indicated locations within their catchment area that they could not visit. The commonest reason was lack of transportation, followed by communication and security. The commonest conditions that the community health workers identified were diarrhoea, malaria, and malnutrition.

Training: five out of nine community health workers could provide information about the most recent training they received. The training lasted 2 days and was provided by WHO and World Vision. All community health workers mentioned case definitions, diagnosis, and specimen collection. All respondents identified AFP as an immediately notifiable condition.

Alert and outbreak investigation: four out of 10 respondents were involved in or participated in an alert verification or investigation. Their roles were mainly in sample collection.

Supervision: respondents received supervision from health authorities above them every month mostly. However, 2/9 reported that they had rarely or never received supervision. Most supervision was provided on an individual basis.

Challenges faced by community health workers: communication problems and not enough training were identified as the main challenges community health workers face in their work.

Laboratories: two public health laboratories were surveyed in the evaluation, one in Upper Nile State (Makal County) and the other in Easter Equatoria State (Ikwoto County). One was at a hospital the other was at a Primary Health Care Corporation (PHCC). Both respondents reported that their primary responsibilities included laboratory sample collection, conducting laboratory tests, laboratory quality control, and supervision. Both respondents were laboratory technicians. Both laboratories were reportedly open every day of the week from 8am to 5pm. One of the laboratories reportedly could accept samples after hours, and both conducted routine laboratory tests.

Reporting, notification: both laboratories did not have standardized reporting forms or standardized forms to transfer specimens to other laboratories and reported their results using cellphones for immediately notifiable conditions. They both did not have a written policy for rapid notification of outbreak specimens (e.g. measles and cholera). Both laboratories reportedly did not have specimen logbooks.

Resources: the hospital laboratory had more resources (i.e. refrigerator, centrifuge, balance scale, generator) than the PHCC laboratory, and they were monitored and calibrated. None of the laboratories had an incubator. Both laboratories had adequate stocks of reagents for the tests they conducted.

Training: both respondents reported that none of their staff had been trained and certified in shipping laboratory specimens.

Central and county level respondents: four senior-level respondents at the central and county level were surveyed, a disease surveillance officer, an EPI manager, a county health director, and an EPI officer. They were located at the State Ministry of Health or the Ministry of Health and had spent between 5 and 240 months in IDSR/EWARN. Their primary responsibilities in IDSR/EWARN are as indicated in the chart below. They also had non-IDSR/EWARN responsibilities-case management, administrative duties, and emergency response.

Review of IDSR data: the respondents reported that they all reviewed the IDSR data to identify discrepancies, missing data, significant variations in numbers, and unusual or new diseases.

Feedback to surveillance or health staff: when asked how often they gave feedback to their direct reports, the majority gave daily and weekly feedback. They gave the feedback using various methods, including email, phone calls, and facility calls.

Supervision, meetings with direct reports: three out of four respondents indicated that they supervised health staff on data collected weekly using various methods, including email, cellphone, facility visits, and training. Half of them indicated that they held regular meetings with surveillance officers, those who did not blame the lack of funds for holding these meetings. The topics that were discussed at the meetings were primarily to strengthen practices.

Training of surveillance staff: respondents were asked how often they or their agency/organization provided training to surveillance staff reporting to them, and it mainly was sporadically dependent on time and funding.

Alert notification: respondents indicated that they received IDSR/EWARN notifications from health facility staff, surveillance staff, reporting channels, and the community primarily. Three of the four respondents indicated that they maintained an outbreak log at their level. The respondents indicated that their IDSR/EWARN systems were linked with other systems (e.g. alpha-fetoprotein (AFP), measles, malaria).

Resources: respondents indicated that they had several types of resources for alert and outbreak investigations, mostly specimen collection tools and equipment.

Integrated disease surveillance and response/early warning alert and response network bulletins: all respondents found the IDSR/EWARN helpful in monitoring health trends in their areas, assisting in community campaigns, and sharing findings with stakeholders. Other reasons included monitoring timeliness and completeness and providing feedback about the health situation in their countries. The bulletins were shared with surveillance officers, health facilities, laboratories, other partners, and non-governmental organizations via email, verbal summaries, and paper copies.

Changes to IDSR/EWARN requirements, funding: respondents indicated that IDSR/EWARN had expanded in the country since it was implemented. Two out of the four respondents indicated that they had been changes in IDSR/EWARN in the last 2 years. In terms of funding, the respondents indicated that they were unsure of financing IDSR/EWARN for the next 12 months.

Challenges in IDSR/EWARN: respondents identified several challenging parts in implementing IDSR/EWARN, primarily insufficient training and a lack of funding. Other challenges were a lack of communication and a lack of response to outbreak alerts.

Data managers: two data managers were surveyed as part of the evaluation. They were both based in Juba in Central Equatoria State and had spent 8 years working on IDSR/EWARN. Their primary responsibilities were data review, data analysis and interpretation, and the production of weekly bulletins. They also worked on non-IDSR/EWARN data. They reported that IDSR/EWARN data were entered by health facility in-charges, county and state surveillance officers, and monitoring and evaluation officers. They found IDSR/EWARN useful for early outbreak detection, monitoring health trends, and sharing information with partners.

Data entry and cleaning: data managers identified unusual or unexpected data by running the data through MS Excel, and if necessary, calling the data source to check the data entry. Lately submitted data are part of the calculation for completeness, but they reportedly advise the data sources to send their subsequent reports early. Missing data are also reportedly sent back to the source for re-entry.

Data storage and backup: respondents reported that data are stored locally and backed up by weekly downloads on different external drives or the cloud.

Data management, analysis: respondents reported that data are analyzed based on demands, either daily, weekly, or monthly. The data managers also analyze alpha-fetoprotein, Guinea Worm, and the other IDSR/EWARN data. They analyze the data using EWARS, MS Excel Kobo tool, or mapping software and share the results with surveillance officers and IDSR/EWARN stakeholders in WHO and the Ministry of Health for decision-making.

Challenges in IDSR/EWARN: the data managers reported challenges. They indicated that they would like to receive training on GIS, SPSS, and different data analysis tools. They suggested that IDSR/EWARN could be strengthened with quarterly training for all national and state data managers.

Suggestion to improve IDSR/EWARN: the survey respondents at all levels had various suggestions to improve IDSR/EWARN. The respondents needed more IDSR training, simulations, and supervision at all levels in addition to ample resources, e.g. funding, transporation and the EWARs and ODK phones for communication of surveillance information.

Summary of surveillance attributes: the IDSR/EWARN system was rated simple, flexible, medium to high data quality, medium to high acceptability, and medium representativeness (Table 1, Table 1 (suite)). Stability was rated high overall, and usefulness was rated high. Laboratory-based attributes, simplicity was rated high, data quality medium, and timeliness was medium to high, while stability was low (Table 2).

Discussion

The independent IDSR/EWARN evaluation revealed several findings. Indicator data show improving performance in terms of timeliness and completeness of IDSR data from the beginning of 2021 to week 16 and then a slight depression of timeliness by week 32, while completeness remained high. Event-based surveillance was active at the beginning of the year and in week 32. There was inadequate sample collection to investigate acute watery diarrhoea, bloody diarrhoea, and acute jaundice syndrome alerts. Respondents in all cadres had substantial experience working in IDSR/EWARN. All respondents performed the various IDSR/EWARN tasks and duties as expected. There was adequate knowledge of case definitions and alert thresholds of priority health conditions and the timing of reporting. There was sufficient feedback using a variety of methods, although simplified feedback is needed at lower levels. Some community health workers were not familiar with IDSR/EWARN. Regular supervision from the higher levels was lacking for, the lower levels. Laboratory respondents reported a lack of standardized reporting forms, specimen transfer forms, and laboratory equipment. In terms of surveillance attributes, the IDSR/EWARN system was rated simple, flexible, with medium to high data quality, medium to high acceptability, and medium representativeness. Stability was rated high overall, and usefulness was rated high. For laboratory-based attributes, simplicity was rated high, data quality medium, and timeliness was medium to high, while stability was low.

There were a few performance gaps that were found in the evaluation. In the laboratories, confirmation of priority diseases by the laboratories needs to be strengthened. Specimen collection for suspected acute watery and bloody diarrhoea was lacking. There is a lack of standardized reporting forms, specimen transfer forms, and laboratory equipment. Health facilities need more regular supervision from the higher levels, and community health workers need more training on IDSR/EWARN. These gaps point to a lack of resources, and indeed, we identified that the IDSR/EWARN system needs more resources, particularly for communication and transport and to confirm priority diseases. Staff at all levels requested more training in IDSR/EWARN. South Sudan is implementing all components of the revised IDSR technical guidelines, given its historical use of EWARN, prioritizing rapid notification and response to epidemic-prone diseases and its early adoption of IDSR. South Sudan also relies on event-based surveillance. There are performance gaps primarily due to a lack of resources; the country is performing relatively well given its context and vast, remote areas. Several recent IDSR evaluations have indicated that training is one of the primary interventions needed for improved performance [20,21].

WHO-AFRO has started virtual training in IDSR [22]. However, focused and sustained provision of resources, including funds and equipment, is likely to lead to sustained improvement beyond training. It may be a waste of resources to conduct training for health personnel who do not have the tools to implement their training. The lack of resources for public health laboratories is an ongoing problem in several countries in the African region, and the continuing COVID-19 pandemic has worsened this [23]. The evaluation had a few limitations. The COVID-19 pandemic limited the scope of the assessment, given the restrictions on travel. Funding also limited the size of the local team to one person. Some respondents did not fill out the questionnaires, and this can limit the generalization of the findings. The evaluation was carried during the COVID-19 pandemic, and the team adapted the methods to the pandemic and triangulated the data to provide comprehensive findings. However, it is possible that the findings from the sites that did not respond could be different from those who responded, which could have introduced a selection bias. Using mixed methods (i.e. qualitative and quantitative) allowed the evaluation team to use various data sources to triangulate the evaluation results.

Conclusion

Since the inception of IDSR in South Sudan in 2006, surveillance and response capacities have improved but remain below the IDSR program targets and the IHR (2005). All efforts should be made to maintain the surveillance performance achieved by week 16 of 2021 for both indicator and event-based surveillance and was still almost at the same level at week 32 of 2021. The information generated from the improved reporting performance should be used for public health action. For instance, rapid response teams should respond to all outbreak alerts through outbreak investigations and special epidemiological studies. Refresher training needs to be provided to all levels below the central level, particularly for the community and the health facility level. Support supervision should be strengthened for all levels. Feedback to the health facilities and communities needs to be developed and maintained

Competing interests

The authors declare no competing interests.

Authors' contributions

John Rumunu, and Joseph Francis Wamala analyzed the data and prepared the manuscript. All the authors have read and agreed to the final manuscript.

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Research

Joint external evaluation of the international health regulations (2005) capacity in South Sudan: assessing the country´s capacity for health security

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Abstract

Introduction: joint external evaluation is a voluntary and collaborative process to assess a country´s capacity under International Health Regulations (2005) to prevent, detect, and respond to public health threats. The main objective is to measure a country´s status in building the necessary capacities to prevent, detect, and respond to infectious disease threats and establish a baseline measurement of capacities and capabilities. The Republic of South Sudan conducted the Joint External Evaluation from 16-20 October 2017, where its capacities were assessed to public health threats per the International Health Regulation (2005).

Methods: cross-sectional descriptive study of the Joint External Evaluation process and the findings are described along with major findings and recommendations for the country.

Results: South Sudan's overall mean score across 48 indicators was 1.5 (min= 1, max= 4) and 42/48 indicators (87.5%) scored < 2 on a 1 to 5 scale. Technical areas in the prevent category with the lowest score were antimicrobial resistance, biosafety and biosecurity, and National legislation, policy, and financing. In the detect category, the mean score was 2. Technical areas with the lowest mean scores were workforce development and the National Laboratory System. Preparedness, medical countermeasures, personnel deployment, linking public health, and security authorities had the lowest scores in the respond category. Chemical events, radiation emergencies, and points of entry had a score of 1 in the other IHR-related hazards and points of entry category.

Conclusion: South Sudan's mean score of 1.5 can be attributed to several civil conflicts experienced, which have impacted negatively on the health system. Recommendations from the Joint External Evaluation need to be implemented and these must be aligned with the costed National Action Plan for Health Security.

Introduction

Between 2001 and 2021, several epidemics and pandemics have posed a severe threat to global health security. These epidemics and pandemics include Severe Acute Respiratory Syndrome (SARS), avian influenza subtypes (H5N1 and H7N9) in Southeast Asia and China, Middle East Respiratory Syndrome (MERS) in the Middle East and South Korea, Ebola virus disease (EVD) in West Africa. In addition, most recently, coronavirus disease 2019 (COVID-19) was first detected in China and has spread to every country in the world. These infectious diseases are mainly driven by the emergence and spread of new pathogens, globalization of travel, food, medicines, antimicrobial resistance rise, and accidental spillover of biohazard agents [1]. The morbidity, mortality, and economic impact of such public health threats can be enormous [2,3]. For example, COVID-19 has resulted in 260 million confirmed cases, and over 5 million deaths as of November 30th, 2021, with a contraction of the global economy, experienced during the recession 80 years ago [4-6].

In the World Health Organization (WHO) Africa Region (AFRO), an acute public health event (PHE) occurs every 3-4 days totalling more than 150 PHEs every year, putting the entire region at high risk of health security threats [7,8]. Some countries like South Sudan face a double jeopardy of PHEs and prolonged armed conflicts. South Sudan has witnessed a protracted humanitarian crisis triggered by an armed conflict that erupted in 2013, disrupted the country's health system, livelihood, and economy [8]. This has resulted in a weak health system with low immunization coverage (i.e. pentavalent-3 coverage was 45% in 2019), leading to an outbreak of vaccine-preventable diseases such as measles in 2018 [9].

WHO member states drafted the international health regulation (IHR 2005) which was adopted by the World Health Assembly (WHA) in 2005 based on the lessons learnt from the first pandemic of the 21st century caused by SARS [10]. The IHR (2005) mandates all countries to develop and strengthen their core capacities to prevent, detect, assess, report, and respond to public events and other hazards [11]. The IHR (2005) came into force in 2007, with all signatory countries given five years to develop the core capacities of IHR (2005). As of 2014, only 30% of states parties had met the required capabilities. In 2015, WHO recommended that "countries move from exclusive self-assessment to approaches that combine self-evaluation, peer review, and voluntary external evaluations involving a combination of domestic and independent experts" [12,13]. In that perspective, WHO developed the joint external evaluation (JEE) process and the JEE tool in February 2016 as part of the IHR (2005) monitoring and evaluation framework to determine countries´ capacity to prevent, detect, and respond to public health threats [14,15]. The JEE was conducted in South Sudan from 16-20 October 2017 [16]. The objective of this study is to document the country´s capacities to prevent, detect and respond to public health threats per the IHR (2005) core capacities. The findings guided the development of the post-JEE costed national action plan for health scurity (NAPHS) [17].

Methods

Study design and area: we conducted a cross-sectional descriptive study of the JEE processes conducted for South Sudan in Juba. The JEE was performed using the WHO guidelines and JEE tool. It consists of 19 technical areas structured into four main categories and 48 questions/indicators (prevent, detect, respond, and other IHR-related hazards and points of entry (PoE). The 19 technical areas comprise 48 indicators that are measured by scale criteria ranging from 1 to 5 (1 = no capacity, 2 = limited capacity, 3 = developed capacity, 4 = demonstrated capacity, and 5 = sustainable capacity) [5] (Table 1). The scores are represented by different colors 1= red, 2 and 3= yellow, and 4 and 5= green [13] (Table 1). Furthermore, the 19 technical areas were categorized in four areas: prevent, detect, respond, and IHR related hazards and points of entries. The first stage of the evaluation is an internal self-assessment completed by the country using self-reported data for the various indicators on the JEE. In South Sudan, this was done from 16 to 20 October 2017. Before the implementation of the JEE, a 1-week consultative meeting was conducted. The phase one process began with the setup of a multi-disciplinary and multi-sectoral team of 25 persons comprising technical departments among key ministries (e.g. health, humanitarian affairs, justice, animal resource and fisheries, environment and forestry, agriculture, wildlife and tourism, petroleum, immigration, civil aviation authority, food and drugs authority. The team comprised nine experts from different institutions such as WHO, the Food and Agriculture Organization (FAO), and different countries, including Nigeria and the United Republic of Tanzania. External subject-matter experts were identified with support from WHO AFRO, and the country´s internal evaluation report was shared with them. Before coming into the country, the team reviewed this self-assessment data, which provided a baseline understanding of the country´s health security capabilities.

There was a one-week workshop from 16-20 October 2017 that facilitated in-depth discussion of the self-reported data and structured site visits to Juba international airport and Nimule land crossing border points. They have joined hands with an 25 national teams of experts, including other identified government agencies, none-governmental organizations (NGOs), and united nations (UN) agencies. The external assessment team reviewed the self-assessment report and associated reference documents; discussed their observations and questions with the national experts; conducted site visits at Nimule land crossing in Eastern Equatoria state and Juba International Airport (JIA), and assigned scores to each of the 48 indicators following consensus with the team of national experts. After conducting the evaluation visit, the evaluation team drafted a report that identified status levels for each indicator and analyzed the country´s capabilities, gaps, opportunities, and challenges. The report was shared with the ministry of health (MoH). In addition, with permission from the MoH, the report was shared among various stakeholders. The objective of sharing the report was to facilitate support to implement identified best practices, address challenges, develop monitoring, accountability and evaluation tools.

Data analysis and presentation: the South Sudan JEE scores for the 19 technical areas were analyzed using microsoft excel for descriptive statistics. The overall mean score of the South Sudan score was then calculated.

Ethical clearance and approval: administrative clearance for this study was provided by the ministry of health of South Sudan. Moreover, the Research Ethics Review Board of Ministry of Health provided clearance for the publication of manuscript under (MoH/RERB/D.03/2022) clearance number. Besides, WHO provided executive clearance for the publication of the manuscripts (WHO ePub-IP-00331327-EC).

Results

On a scale of 1-5 overall mean score for the 48 indicators in the 19 technical areas was 1.5 (no to limited capacity). Out of 48, 30 (63%) showed the country has no capacity under the IHR (2005) requirement for health security. A total of 42 out of 48 indicators (88%) scored under the no capacity and limited capacity category. Figure 1 illustrates the combined indicators score in the country. In the prevent category, seven technical areas with 15 indicators were included during the JEE. The mean score was again 1.5 (no to limited capacity). Nine out of 15 (60%) indicators had a 1 (no capacity) score. Technical areas with the lowest mean scores were antimicrobial resistance (AMR) and biosafety and biosecurity with a score of 1 each (no capacity) (Table 2). The indicator scores ranged from 1.3 to 3 in the Detect category, with 11 of the 13 indicators (86%) in 4 technical areas having a score ≤ 3. The mean score was 2 (limited capacity), and technical areas with the lowest mean scores were workforce development (score 1.3) and National Laboratory System with a score of 1.5 (Table 3). In the Respond category, the scores ranged from 1 to 2, with all the 14 indicators in the five technical areas having a score of 1.4 and below. The mean score was 1.2, and technical areas with the lowest mean score were preparedness, medical countermeasures and personnel deployment, and linking public health and security authorities with a score of 1 each (Table 4). In the other IHR-related hazards and point of entry category, all six indicators in three technical areas had a score of 1 each (Table 5).

Table 1: joint external evaluation core capacity technical areas and scores		
Thematic area	**Technical areas**	**Number of indicators**
Prevent	National legislation, policy and financing	2
	IHR coordination, communication and advocacy	1
	Antimicrobial resistance	4
	Zoonotic diseases	3
	Food Safety	1
	Biosafety and biosecurity	2
	Immunization	2
Detect	Workforce development	3
	National laboratory system	4
	Real-time surveillance	4
	Reporting	2
Respond	Preparedness	2
	Emergency response operations	4
	Linking public health and security authorities	1
	Medical countermeasures and personnel deployment	2
	Risk communication	5
Other IHR related hazards and PoEs	Points of entries	2
	Radiation emergencies	2
	Chemical events	2
Source: joint external evaluation tool: international health regulations - SCORE for health data		

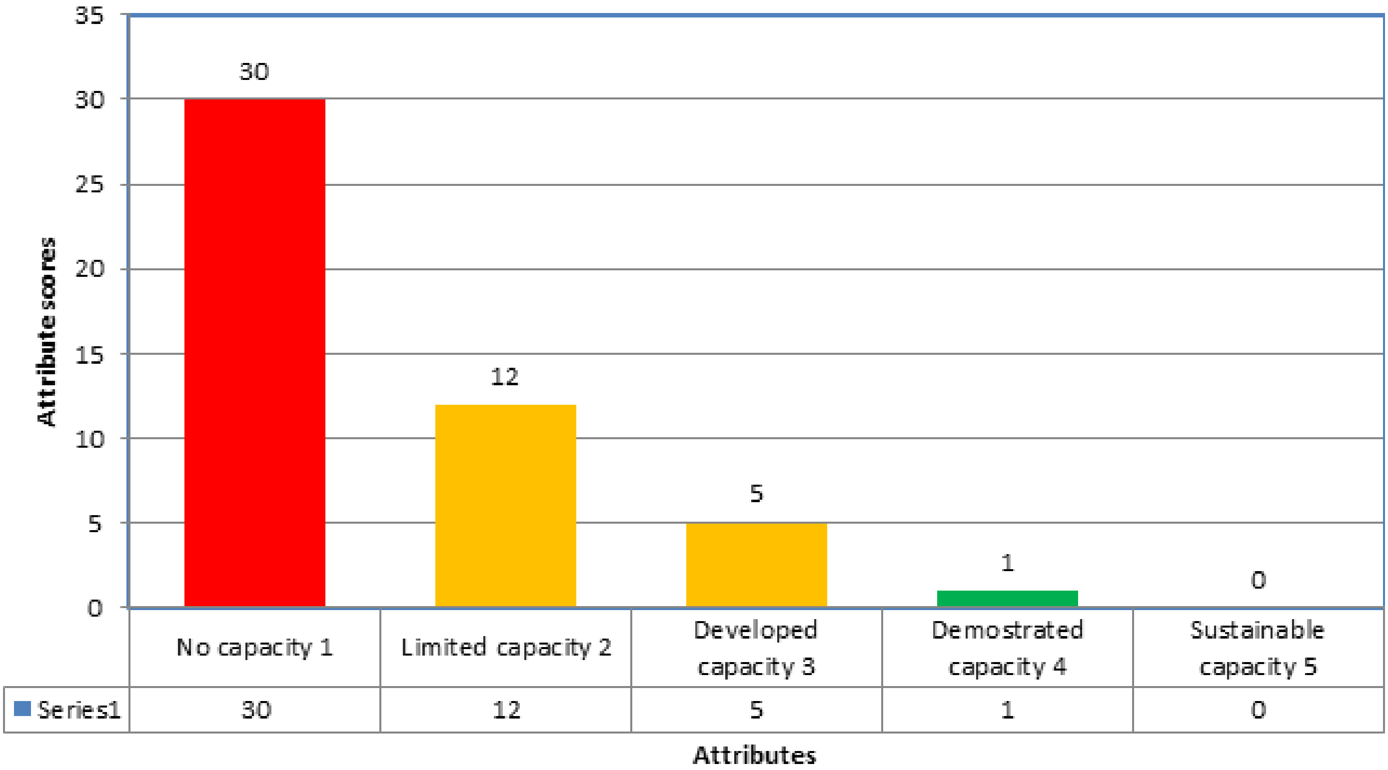

Figure 1: number of indicators per score during the JEE, October 17-20 the Republic of South Sudan

Table 2: prevent category indicators score, 16-20 October 2017 the Republic of South Sudan		
Technical areas	**Indicators**	**Score**
National legislation, policy and financing	P.1.1 legislation, laws, regulations, administrative requirements, policies or other government instruments in place are sufficient for implementation of IHR (2005)	Limited capacity-2
	P.1.2 the state can demonstrate that it has adjusted and aligned its domestic legislation, policies and administrative arrangements to enable compliance with IHR (2005)	No capacity-1
IHR coordination, communication and advocacy	P.2.1 a functional mechanism is established for the coordination and integration of relevant sectors in the implementation of IHR	Limited capacity-2
Antimicrobial resistance	P.3.1 antimicrobial resistance detection	No capacity-1
	P.3.2 surveillance of infections caused by antimicrobial-resistant pathogens	No capacity-1
	P.3.3 healthcare-associated infection (HCAI) prevention and control programs	No capacity-1
	P.3.4 antimicrobial stewardship activities	No capacity-1
Zoonotic diseases	P.4.1 surveillance systems in place for priority zoonotic diseases/pathogens	Developed capacity-3
	P.4.2 veterinary or animal health workforce	Limited capacity-2
	P.4.3 mechanisms for responding to infectious and potential zoonotic diseases are established and functional	No capacity-1
Food safety	P.5.1 the country has IBS or EBS and monitoring systems in place to monitor trends	Limited capacity-2
	and detect foodborne events (outbreak or contamination)	
Biosafety and biosecurity	P.6.1 whole-of-government bio-safety and bio-security system is in place for human, animal and agriculture facilities	No capacity-1
	P.6.2 biosafety and bio-security training and practices	No capacity-1
Immunization	P.7.1 vaccine coverage (measles) as part of a national program	No capacity-1
	P.7.2 national vaccine access and delivery	Developed capacity-3
Total score (N=15)		23
Mean score		23/15 (1.5)
Note: 1(red)="attributes of a capacity do not exist or are not in place"; 2 (yellow)= "attributes of a capacity are in the development stage (some are achieved, and some are undergoing; however, the implementation has started)"; 3 (yellow) = "attributes of a capacity are in place; however, there is the issue of sustainability and measured by lack of inclusion in the operational plan in national health sector planning (NHSP) and/or secure funding";4 (green) = "attributes are in place, sustainable for a few more years and can be measured by the inclusion of attributes or IHR (2005) core capacities in the national health sector plan-green";5 (green) = "attributes are functional, sustainable and the country is supporting other countries in its implementation. This is the highest level of the achievement of implementation of IHR (2005) core capacities" (10)		

Table 3: detect category indicators scores, 16-20 October 2021 the Republic of South Sudan		
Technical Areas	**Indicators**	**Scores**
National laboratory system	D.1.1 laboratory testing for detection of priority diseases	2
	D.1.2 specimen referral and transport system	1
	D.1.3 effective modern point-of-care and laboratory-based diagnostics	2
	D.1.4 laboratory quality system	1
Real-time surveillance	D.2.1 indicator- and event-based surveillance systems	3
	D.2.2 interoperable, interconnected, electronic real-time reporting system	2
	D.2.3 integration and analysis of surveillance data	3
	D.2.4 syndromic surveillance systems	4
Reporting	D.3.1 system for efficient reporting to FAO, OIE and WHO	3
	D.3.2 reporting network and protocols in-country	2
Workforce development	D.4.1 human resources available to implement IHR core capacity requirements	1
	D.4.2 FETP or other applied epidemiology training program in place	1
	D.4.3 Workforce strategy	2
Total scores (N=13)		26
Mean score		26/13 (2)

Table 4: respond category indicators scores, South Sudan (October 16-20, 2017)		
Technical areas	**Indicators**	**scores**
Preparedness	R.1.1 national multi-hazard public health emergency preparedness and response plan is developed and implemented	1
	R.1.2 priority public health risks and resources are mapped and utilized	1
Emergency response operations	R.2.1 capacity to activate emergency operations	1
	R.2.2 EOC operating procedures and plans	1
	R.2.3 emergency operations program	1
	R.2.4 case management procedures implemented for IHR relevant hazards.	2
Linking public health and security authorities	R.3.1 public health and security authorities (e.g. law enforcement, border control, customs) are linked during a suspect or confirmed biological event	1
Medical countermeasures and personnel deployment	R.4.1 system in place for sending and receiving medical countermeasures during a public health emergency	1
	R.4.2 system in place for sending and receiving health personnel during a public health emergency	1
Risk communication	R.5.1 risk communication systems (plans, mechanisms, etc.)	1
	R.5.2 internal and partner communication and coordination	2
	R.5.3 public communication	1
	R.5.4 communication engagement with affected communities	1
	R.5.5 dynamic listening and rumour management	2
Total score (N=14)		17
Mean score		17/14 (1.2)

Table 5: other international health regulation-related hazards and point of entry indicators score, South Sudan (October 16-20, 2017)		
Technical areas	**Indicators**	**Scores**
Points of entry (PoE)	PoE.1 routine capacities established at points of entry	1
	PoE.2 effective public health response at points of entry	1
Chemical events (CE)	CE.1 mechanisms established and functioning for detecting and responding to chemical events or emergencies	1
	CE.2 enabling environment in place for the management of chemical events	1
Radiation emergencies (RE)	RE.1 mechanisms established and functioning for detecting and responding to radiological and nuclear emergencies	1
	RE.2 enabling environment in place for the management of radiation emergencies	1
Total score (N=6)		6
Mean score		6/6 (1)

Discussion

The JEE of South Sudan, conducted in 2017 documented the country´s capacities to prevent, detect, and respond to public health threats per the IHR (2005) core capacity. The evaluators found the overall mean score of 48 indicators in 19 technical areas was 1.5 on a scale of 1-5. Out of 48 indicators, 30 (63%) showed the country has no capacity under the IHR (2005) requirement for health security. A total of 42 out of 48 indicators (88%) scored under the no capacity and limited capacity category. The outcome of JEE in South Sudan reaffirms the under-developed core capacities in all the 19 technical areas categorized in prevent, detect, respond, and IHR related hazards and points of entries. The low core capacities in place are similar to most African countries where JEE has been conducted [18]. A study conducted in 55 IHR states parties showed that 43 out of 48 indicators scored less than 4. Hence, countries in the WHO Regional Office for Africa (WHO-AFRO) performed poorly compared to countries in other regions [18,19]. In the 'prevent' category, the mean score was again 1.5 (no to limited capacity) 9 out of 15 (60%) indicators had a score of 1 (no capacity). The few areas with relatively well-developed capacities were mainly made by vertical programs, usually with external funding. For example, the vertical expanded program for immunization (EPI) national program is usually well resourced in human resources, cold chain, and training. The lowest score of no capacity was observed under antimicrobial resistance (AMR) and Biosafety/Biosecurity areas like most countries in the WHO-AFRO region due to lack of policy focusing in these areas [18,20]. At the same time, under the 'Detect' category, the score improved due to the investment in the Integrated disease surveillance and response (IDSR) system with accompanied reporting. The IDSR system has been robust enough to detect most outbreaks in South Sudan. The long years of constant investment in IDSR have paid the dividend [21,22]. Since the specific objectives of IDSR are to strengthen, coordinate, and streamline multiple disease surveillance activities to achieve an integrated, comprehensive public health surveillance system that serves all public health priorities at each level of the health system. This resulted in a strong IHR core capacities capacity in African countries that have implemented IDSR strategies over a long time [20].

In South Sudan, the health workforces have generally been low in numbers and skill mix. This is due to inadequate institution training, poor civil service remunerations, and high turnover. A similar finding was observed in the JEE; workforce development scored the lowest mean scores (i.e.

1.3). Countries across the WHO-AFRO region and worldwide faced a shortage of health workforce [19]. The health workforce is the foundation of the health system and essential to delivering quality health services, ameliorating population health, assuring universal health coverage (UHC), and attaining sustainable development goals (SDG). The 2013 world health assembly (WHA) and the 'global strategy for human resource for health (HRH): workforce 2030' acknowledge that health systems can perform well if they have sufficient, motivated, trained, responsive, competent and equitably distributed health workforce [23,24]. Countries in the WHO-AFRO region are expected to implement HRH strategy by 2030; however, implementation is lagging due to a lack of government commitment and health system investment [24]. As far as core capacities in the 'respond' category are concerned, they were all none or limited due to the underlying weak health system. This was manifested by weak coordination at the national level, limited community engagement due to a high level of illiteracy and meagre government resource investment into health which is less than 2% of gross domestic product (GDP) annually. In addition, the civil conflicts and the ongoing humanitarian situation added further stress to an already fragmented health system resulting in further decimation of the healthcare system [25]. Despite the challenges, the MOH, with support from partners, started constructing the public health emergency operation center (PHEOC). Once completed, it will drastically improve emergency response operations by providing strong coordination. Besides, during the JEE, review and completion of the national action plan for health Security (NAPHS) was underway. The NAPHS advocate for a multi-sectorial approach for better coordination of public health emergency preparedness and response at various levels.

For the category other IHR-related hazards and points of entry, the country had either no capacity or limited capacity as most other African countries [18]. Among the other IHR (2005) hazards, the country has a minimal ability to manage radiation and chemical events. As an oil-producing nation, South Sudan is at risk of chemical spills and thus, developing capacities in these technical areas is also critical [26]. The very low PoE score has far-reaching consequences of increased travel and trade between South Sudan and foreign countries. Because of the high volume of travelers, steps have been taken to strengthen ports health at Juba international airports and Nimule border crossing points. Our study shows that strong and participatory country self-assessment is critical to successfully implementing high-quality JEE and country ownership of its outcome. Furthermore, pilot site visits to selected national agencies were useful and substantially contributed to interpreting the objective and scoring of JEE technical areas. This facilitated collaboration between national officials and external experts [27]. Given the high burden of outbreaks and other public health emergencies, it is important the finding of JEE is used as it provides robust evidence to revise or develop the NAPHS [28]. The limitation of this study is that the scoring was done subjectively. At the same time, the participants from other non-health sectors did not entirely understand the scope of the questions. The knowledge of IHR (2005) was also limited among the participants, making it difficult for well-informed discussions.

Conclusion

The policy implication of the findings of JEE is that the country must put in place plans and processes to progressively improve IHR core capacities in the context of health systems recovery. Our findings pointed to critical gaps in all the IHR (2005) core capacities and calls for urgent development and implementation of a NAPHS. Based on our findings, we propose the following recommendations. First, a mid-term review of the national IHR (2005) core capacities; proposed to assess ongoing efforts to fill the critical gaps identified during the study. Second, the country to finalize the NAPHS with a clear implementation framework. Besides, the country should take advantage of resources and partnerships available during acute emergencies such as the COVID-19 pandemic to improve some core capacities, particularly the NPHL and PHEOC.

Competing interests

The authors declare no competing interests.

Authors' contributions

Argata Guracha Guyo conceived and wrote the first draft of the manuscript. All authors read and provided significant inputs into all drafts of the manuscript, agreed to be accountable for all aspects of the work and approved the final draft of the manuscript for publication.

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Case study

Use of mobile medical teams to fill critical gaps in health service delivery in complex humanitarian settings, 2017-2020: a case study of South Sudan

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Abstract

The vulnerable populations in the protracted humanitarian crisis in South Sudan are faced with constrained access to health services and frequent disease outbreaks. Here, we describe the experiences of emergency mobile medical teams (eMMT) assembled by the World Health Organization (WHO) South Sudan to respond to public health emergencies. Interventions: the eMMTs, multidisciplinary teams based at national, state and county levels, are rapidly deployed to conduct rapid assessments, outbreak investigations, and initiate public health response during acute emergencies. The eMMTs were deployed to locations affected by flooding, conflicts, famine, and disease outbreaks. We reviewed records of deployment reports, outreach and campaign registers, and analyzed the key achievements of the eMMTs for 2017 through 2020. Achievements: the eMMTs investigated disease outbreaks including cholera, measles, Rift Valley fever and coronavirus disease (COVID-19) in 13 counties, conducted mobile outreaches in emergency locations in 38 counties (320,988 consultations conducted), trained 550 healthcare workers including rapid response teams, and supported reactive measles vaccination campaigns in seven counties [148,726, (72-125%) under-5-year-old children vaccinated] and reactive oral cholera vaccination campaigns in four counties (355,790 vaccinated). The eMMT is relevant in humanitarian settings and can reduce excess morbidity and mortality and fill gaps that routine health facilities and health partners could not bridge. However, the scope of the services offered needs to be broadened to include mental and psychosocial care and a strategy for ensuring continuity of vaccination services and management of chronic conditions after the mobile outreach is instituted.

Introduction

The world´s youngest nation, South Sudan, descended into civil war in December 2013, followed by another significant flare-up in 2016 after a failed peace process and has been reeling in the effects of the prolonged conflict ever since [1,2]. The cumulative impact of the conflict and attendant humanitarian crisis has resulted in 8.3 million people in need of humanitarian assistance, 7.2 million people experiencing severe food insecurity, and 2.0 million internally displaced persons (IDP) in 2021 [3-6]. Severe recurrent flooding, acute food insecurity and famine, sub-national violence, mass displacement, disease outbreaks and the COVID-19 pandemic are among the top drivers of humanitarian needs among the communities [7]. The provision of essential health services has been complicated by a health system that is under-developed, under-resourced, and highly dependent on the development and humanitarian partners with limited access to essential health services occasioned by the poor road system, insecurity, and natural disasters like floods [8]. South Sudan has amongst the poorest health indicators owing to poor access to essential services and severe disruption of health service delivery during the decades of civil war. The maternal mortality rate at 1,150 per 100,000 live births is the highest in the world, while the under-5-year-old mortality rate at 98 per 1000 live births is among the highest globally [9]. The routine immunization coverage for vaccine-preventable diseases was estimated at <50% in 2020 with lower coverages in the conflict-affected counties in Jonglei, Unity and Upper Nile, which predisposed the vulnerable population to multiple diseases outbreaks [10,11]. Measles outbreaks were confirmed in 24 out of 47 counties, four UN Protection of Civilians (PoC) sites in 2019 and five counties in 2020 [10,11].

The use of mobile medical teams, usually self-sufficient, multidisciplinary medical teams with sufficient flexibility to deploy rapidly, is a common modality in humanitarian emergencies. Mobile clinics deliver preventive (i.e. immunization, screening, and health education) and curative (i.e. treatment of common morbidities and minor surgeries) services to communities that are unable to access health facilities [12]. The mobile health services are operated with clear referral pathways for services that cannot be rendered by the mobile clinic [12]. Mobile clinics are common and favored in humanitarian crises, although they are limited in coverage, expensive and logistically burdensome, and lack sustainability and continuity for chronic illnesses [12-14].

Case study

The rationale for emergency mobile medical team (eMMT)

The vulnerable populations in the humanitarian crisis face frequent disease outbreaks and breakdowns in essential services and require an emergency response to provide timely and essential services to prevent and reduce excess morbidity and mortality [15]. With almost 80% of health services being delivered by health partners, the South Sudan health system can barely provide routine service delivery and respond to emergencies [16]. Health service delivery is fragmented and faces enormous challenges due to limited access as only 44% of the population live within 5km of a health facility [17]. The country experiences frequent humanitarian and public health emergencies that exacerbate the needs of vulnerable communities. The World Health Organization (WHO) South Sudan has a standby emergency mobile medical teams (eMMT) within its emergency program. The eMMT is deployed to verify, investigate, and respond to disease outbreaks and other public health emergencies. The WHO eMMT operates within the framework of the Health Cluster with the frontline Health Cluster partners fulfilling their mandate of providing basic health and essential services including surveillance and response to emergencies in fragile, conflict, and vulnerable settings. WHO provides overall technical backstopping for the health cluster response and strategy, and is a provider of last resort that fills in health response gaps in locations where the frontline partners are either lacking or are overwhelmed based by the scale of the acute crisis and scope of response needs. It is in these settings that the WHO eMMTs are deployed to augment the health cluster response. Here we describe the teams´ experiences, challenges, and usefulness in a complex humanitarian setting in South Sudan and share the lessons learned and recommendations for improving the intervention.

Description of eMMT

WHO South Sudan established the eMMT in 2016. The intent was to have a readily deployable capacity to conduct assessments, investigations, and institute initial life-saving integrated services during acute emergencies. The eMMTs are WHO personnel engaged on short-term contracts to support response to acute emergencies. The eMMTs comprise epidemiologists, clinicians or doctors, nurses, laboratory specialists, nutritionists, health promotion experts, and public health officers or water, sanitation, and hygiene (WASH) experts. The teams are constituted to ensure they are self-sufficient during their field deployment. For each deployment, the team composition is tailored to the unique response needs of the emergency at hand. Each member of the team plays specific roles and responsibilities on the team. The epidemiologist is the team lead and provides technical leadership during outbreak investigations and rapid assessments, planning and coordination of mobile outreaches, training and vaccination campaigns, and data analysis and report writing. The clinicians and nurses are tasked to undertake clinical care of patients during the outreaches and vaccination activities while the laboratory personnel are charged with collecting, packaging and transporting samples collected from the field. The public health officer and WASH experts are involved in health promotion and messaging, while the nutritionist is tasked to spearhead the nutrition component of the intervention. All the team members support their respective areas during training organized for the local health workers or partners.

There have been two to three eMMTs under WHO South Sudan during different emergencies depending on the response needs. The teams are based in Juba, state or county level. While the teams based in the states or counties are specific for those locations, the team based in Juba functions to support any location that lacks local capacity and requires support. The eMMTs are standby rapidly deployable within 24-48 hours of receiving an alert or a report from the counties, surveillance officers, implementing health partners, or community informers or leaders. The teams receive orientation on planning and preparing for deployments, conducting mobile medical outreaches, emergency vaccination campaigns and capacity building of local health workers upon joining the team. The teams also undergo trainer of trainers training for the Integrated Disease Surveillance and Response (IDSR) to ensure that they are adequately skilled to build local health workers' capacity to report, detect and investigate alerts or suspected outbreaks, and initiate an appropriate response.

The eMMTs are resourced to undertake their mandates while on field deployments. The materials, tools and support provided are dependent on the intervention planned. The teams are usually equipped with the Ministry of Health (MoH) outpatient registers (used during outreaches), referral forms, and information, education and communication (IEC) materials. In addition, the teams are equipped with emergency health kits (containing essential drugs and supplies required during outreaches), laboratory sample collection kits, water sample collection and testing kits, and first aid supplies. The IDSR, case management and other training materials are also provided to the teams to train local health workers. The operation and logistics support are usually provided through WHO field teams who support securing accommodations and local transportation, while the United Nations Humanitarian Air Services (UNHAS) support transportation from the duty station to response sites. The eMMT interventions are mostly supported through emergency donor-funded projects focused on providing short-term humanitarian aid during acute emergencies.

Interventions implemented by eMMT

We deployed eMMTs to locations with acute emergencies where support is required to supplement the existing local capacities. We deployed the eMMTs to respond to acute emergencies such as infectious disease outbreaks, large-scale population displacements, natural disasters like floods, famine and malnutrition, and breakdown in basic health service delivery where there is no other health partner to fill the critical gap. The eMMTs were deployed to over 35 counties across the country during the period 2017-2020 (Figure 1). The Health Cluster, health preparedness and response coordination forum, agrees on the emergency response locations based on the needs assessments and partner presence. WHO mobilized the eMMTs to provide integrated health and nutrition services. The eMMTs were deployed to conflict-affected locations such as Kajo-Keji and Tambura from 2017 to 2020, and flood-affected locations such as Pibor, Akobo and Mayom in 2019 and 2020. During the deployments, the teams select sites for mobile outreaches in consultation with local health leaders and partners to avoid duplication, set up temporary outreach sites and provide services for two to five days. The sites were revisited as per the schedule prepared to ensure adequate coverage of all the locations in need of mobile services. The integrated health and

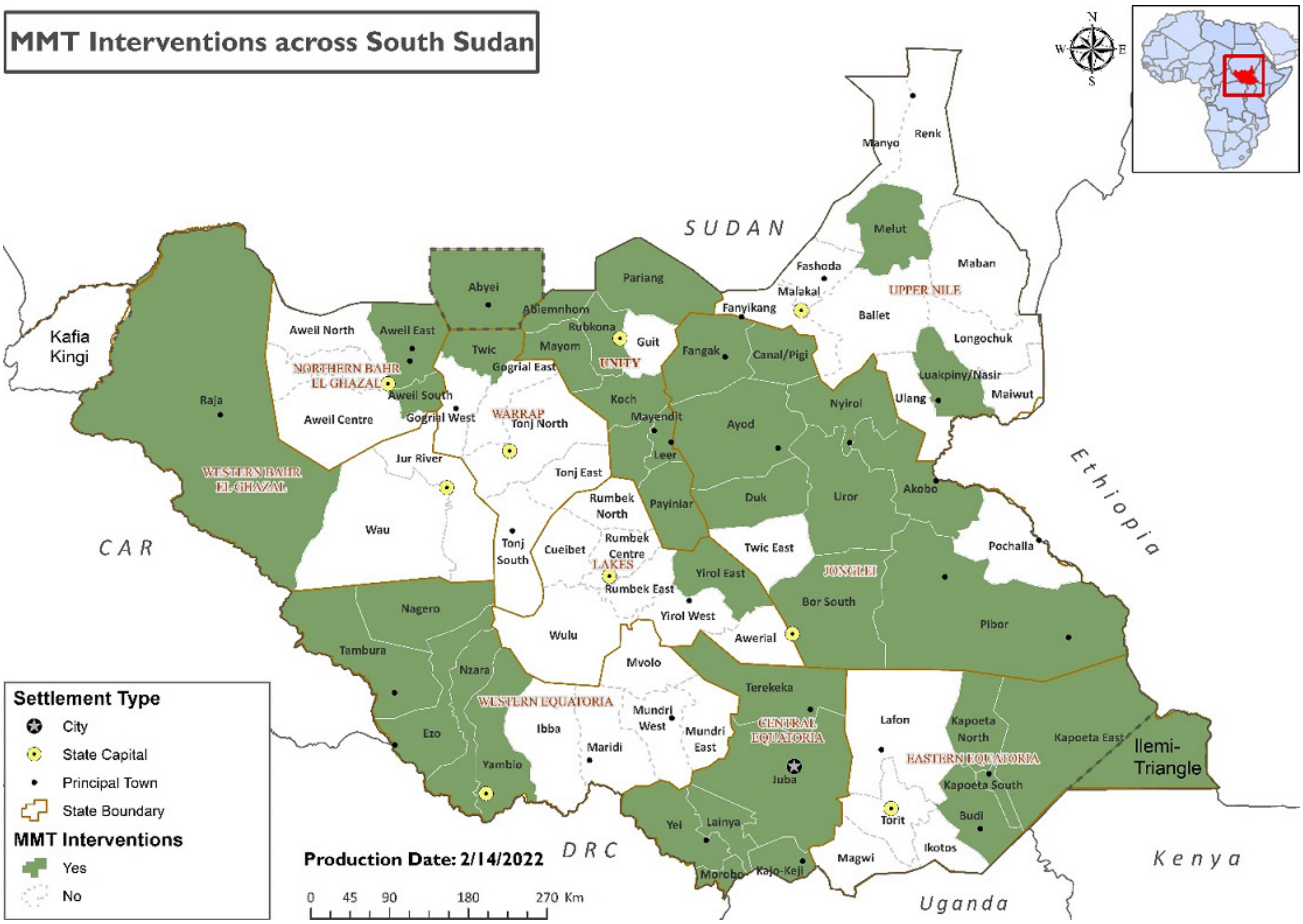

Figure 1: map of South Sudan showing counties where the emergency mobile medical teams´ interventions were implemented, 2017-2020

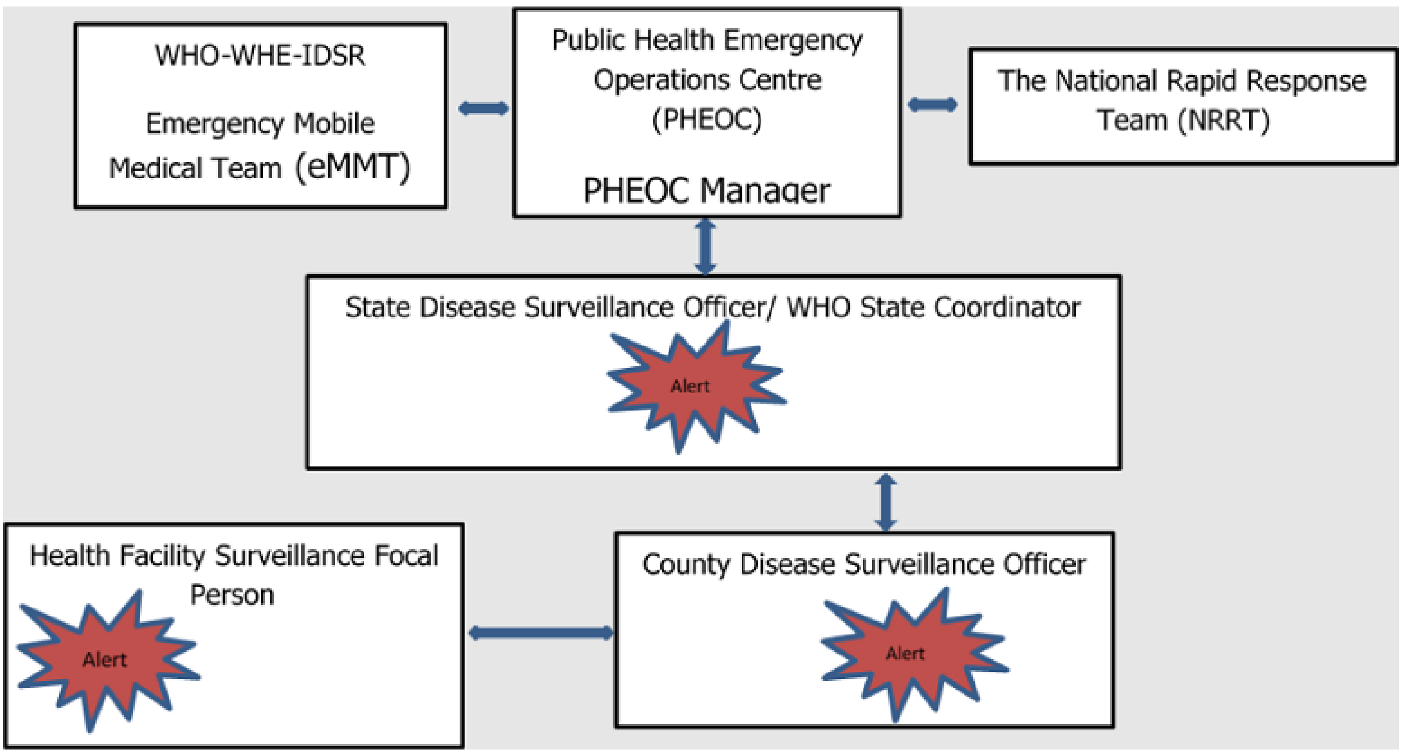

Figure 2: the working relationship between WHO eMMT, PHEOC and NRRT while responding to acute public health events in South Sudan

Table 1: summary of achievements of eMMT interventions in South Sudan, 2017-2020			
Intervention	public health emergency	County	Achievement
Outpatient consultation	OPD and emergencies	38 counties, Bentiu PoC	320988 OPD consultations
Reactive measles vaccination campaign	Measles	Juba, Abyei, Melut, Aweil South, Pibor (Maruwa and Labarab), Bor PoC	148726 vaccinated; coverages achieved: Juba (99%), Abyei (88%), Melut (78%), Aweil South (116%), Pibor-Maruwa and Labarab (72%), Bor PoC (125%),
Reactive oral cholera vaccination campaign	Cholera	Kapoeta East, Kapoeta South, Kapoeta North and Torit,	355790 persons vaccinated; coverages achieved in round 1&2: Kapoeta East [(85058 [(87.7%) vs 75236 (77.6%)], Kapoeta North [(73323 (51.8%) vs 71406 (50.5%)], and Torit [(126895 (79.4%) vs 120452 (75.3%)] Kapoeta South [(70514 (72.7%%) vs 2nd round not done]
Pre-emptive oral cholera campaign	cholera	Bor South	Coverage achieved: 63 280 (88.1%) in round 1 vs 64 137 (89.3%) in round 2
Outbreak investigation	Malaria	Rumbek Centre, Rumbek East, Wulu and Yirol East	Outbreak confirmed; health facilities supplied with emergency kits
	Measles	Juba, Kapoeta East, Pibor,	Outbreak confirmed and responded to
	cholera	Pibor, Kapoeta East and Fangak	The cholera outbreak ruled out
	Rift valley fever	Yirol East	Outbreak confirmed and responded to
	COVID-19	Juba, Torit	Investigated and conducted contacting tracing for the initial COVID-19 cases
	Food poisoning	Bor South, Leer, Kuajok, Aweil	353 patients managed and discharged
Rapid assessments	displacement, floods, conflict, and acute malnutrition	Kajo Keji, Uror, Ayod, Pibor, Renk, Juba, Mayom, Nyirol, Rumbek Centre, Terekeka, Twic East and Nasir	Health facilities assessed and equipped with essential services
Training for health workers (including RRTs)	OPD epidemic-prone diseases	30 counties, Bentiu PoC	550-600 health workers trained
COVID-19 preparedness and response	COVID-19	Juba, Torit	98 RRTs and health workers trained on case investigation and contact tracing
EVD preparedness (training of health workers)	Ebola	Yei, Yambio, Nimule, Juba	65 trained

nutrition services provided by the eMMT include preventive (i.e. routine vaccination, antenatal care, health education and promotion), curative (i.e. outpatient consultation, nursing care, minor surgeries, and referral for severe cases) and nutrition (i.e. screening and referral of severely malnourished cases for inpatient care) services. The outreach services were provided as per the clinical package of services by the Health Cluster and the Basic Package of Health and Nutrition Services by the South Sudan Ministry of Health.

Secondly, the eMMTs are deployed to conduct alert verification and outbreak investigation. Alerts and suspected disease outbreaks are usually generated through the Early Warning, Alert and Response System (EWARS) and communicated to Public Health Emergency Operation Centre (PHEOC) leadership and WHO by PHEOC officers assigned to monitor alerts. The eMMTs are deployed to conduct outbreak investigations and collect patient and environmental samples for laboratory confirmation. In addition, the eMMT initiated health responses for the affected locations by supporting local health facilities, delivering essential commodities and supplies, and disseminating findings to PHEOC and partners to guide further action. The eMMTs have been deployed to investigate suspected outbreaks of cholera in Pibor and Kapoeta East Counties, yellow fever in Nzara County, and Rift Valley fever in Yirol East County, measles and COVID-19 in several counties. The deployment of eMMTs is done in coordination with the National PHEOC, which is charged with coordinating responses in the country. The eMMTs support the PHEOC through on-job training of the national and state Rapid Response Teams (RRT). The RRTs are the Ministry of Health officers who constitute a critical early detection and response arm of the PHEOC. Figure 2 depicts the working relationship between WHO eMMT, PHEOC, and the RRTs in their mandate to conduct early identification, confirmation of, and response to acute public health events.

Thirdly, we have deployed the eMMTs to implement vaccination activities in locations affected by emergencies. The eMMTs have been deployed during confirmed outbreaks to implement reactive measles and cholera vaccination campaigns and pre-emptive Oral Cholera Vaccination (OCV) campaigns in flood-affected locations. The eMMTs implemented vaccination campaigns in several locations, including Kapoeta South and Pibor. The eMMTs utilized standard MoH vaccination registers, cold chain equipment and supplies, and collaborated with local health workers and partners during the campaigns. The eMMTs have also been deployed to provide training on IDSR, case management of common endemic diseases, infection prevention and control (IPC), and Clinical Management of Rape (CMR) for healthcare workers. The IDSR training that targeted surveillance officers and facility in-charges aims to enhance surveillance and reporting by health facilities and is conducted using the adapted IDSR training modules. The case management training targeted clinicians and nurses, while IPC training was meant for clinical cadres and public health officers. Both the case management and IPC training are based on the treatment and IPC guidelines by the MoH and WHO. All the training utilized customized PowerPoint presentations and case study exercises.

Data collection and analysis

Data on the outpatient consultation were extracted from the outpatient registers that are completed during mobile medical outreaches. We obtained the information on the number of health workers trained from the attendance sheet. Training and deployment reports were submitted using a standardized training and field report template utilized by the eMMT to document the interventions and achievements. In addition, we extracted the vaccination campaign data from the field reports and the Ministry of Health´s daily tally sheet and summary sheet filled by the vaccinators and team supervisors during the vaccination exercise. The coverage of the vaccination campaigns was calculated using Microsoft Excel as a proportion of the targeted population.

Achievements eMMT

The eMMT has implemented its intervention in 38 counties spread across nine states, with almost half (42%) of the counties located in Jonglei and Unity States (Figure 1). The interventions implemented ranged from disease outbreak investigations, and implementation of emergency pre-emptive and reactive vaccination campaigns to conducting mobile medical outreaches. Notably, eMMTs have investigated and confirmed rift valley fever outbreaks in 2018. The eMMT investigated measles outbreaks and implemented reactive vaccination campaigns in seven counties during the review period, including Maruwa and Labarab in Pibor, during the widespread measles outbreak in the country in 2019. Labarab and Maruwa are hard-to-reach locations in Pibor Administrative Area, where the eMMT implemented a reactive measles vaccination as the provider of last resort as no partner could access the area. Overall, 148,725 (72-125% coverage) under-5-year-old children were vaccinated in seven locations with confirmed measles outbreaks in 2019 and 2020. Some 355,790 (coverage 51-89% in round 1 and 50-78% in round 2) individuals were reached with oral cholera vaccines in four locations with active cholera outbreaks in 2018. Further, the eMMT implemented a pre-emptive oral cholera vaccination campaign in Bor South, a severe flood county in 2020, and vaccinated 63,280 (88.1%) people in round 1 and 64,137 (89.3%) people in round 2. In 2019 and 2020, the eMMT took the lead in training RRTs and other health workers as part of the country´s preparedness activities for the Ebola Virus Disease (EVD) and COVID-19 pandemic and formed a critical component of the COVID-19 response team after the outbreak was confirmed in the country as members of contact tracers. A summary of some critical achievements is presented in Table 1.

Challenges faced by eMMT

The implementation of the mobile medical team strategy has revealed a few important lessons that can be used to strengthen the future approaches for the intervention. First, there is a need for collaboration and coordination with the local administration and partners on the ground for adequate information on insecurity and access challenges critical for planning. Second, the team composition must be reconstituted and adapted based on the nature of the emergency being responded to, assuring adequate capacity within the team to attend the event. A different set of skills and experiences is required to respond to different emergencies adequately. Thirdly, to ensure the needs of the vulnerable populations are addressed comprehensively, it would be prudent to broaden the scope of the services offered by the eMMTs to include psychosocial and mental care. Mental health and psychosocial disorders, including post-traumatic stress syndrome and depression, are prevalent among conflict-affected populations [18]. There is a high need for mental health services during and after conflicts [19]. The effectiveness of delivering community mental health services through mobile health clinic approach has been demonstrated in rural Haiti [20]. Further, there must be a proper referral linkage with local health facilities where the mobile outreaches are being conducted to attend to severe clinical cases requiring an inpatient or specialized service. Transportation and costs of referring these cases from outreach sites to the receiving facilities should be anticipated and planned. Fifth, there is a need for collaboration between eMMTs and local health workers, including community health workers during outreaches and outbreak investigations for on-the-job training and skills transfer with the view of promoting ownership and sustainability of interventions.

Our operations and delivery of essential services have been affected by multiple factors ranging from insecurity to difficulties in delivering essential commodities and personnel on time to where they are required. Unpredictable security situations, inefficient and costly logistics, rugged terrain and poor road and transportation networks, frequent flooding, and lack of continuity of services the mobile teams offer are some of the key challenges faced. The frequent insecurity flare-ups, displacement of the targeted populations, flooding of airstrips, impassable roads, delays in delivery of essential medicines, vaccines, emergency responders, and funds required for planned activities and attacks on health facilities or health personnel have contributed to the mobile missions being postponed, terminated, or being unsuccessful. Many of the locations served by the mobile teams are hard-to-reach areas that caused the teams to trek for long hours through challenging terrains, mud, or flood water or be flown into the area to reach the vulnerable, isolated groups. Some locations lacked a partner or local authority to address the reported emergencies and required WHO to send in the mobile teams as the provider of the last resort.

The lack of continuity of the services offered by the eMMTs is related to the absence of strategies to ensure the continued provision of vaccination services and the management of the chronic conditions initiated during the mobile outreach. The lack of predictability of the visit by the mobile teams may negatively affect the community´s uptake of the services and the ability of the teams to offer certain services. The other notable challenges encountered include weak public health surveillance and poor mobile network coverage in the conflict-affected counties contributing to delays in receiving and responding to reports of public health events and inconsistent capture and reporting of data from the mobile clinics.

Conclusion

Our experiences illustrated that mobile medical teams are relevant in complex humanitarian settings and can provide basic health services and fill gaps that static health facilities and frontline health cluster partners could not bridge. The eMMTs have demonstrated their importance and potential in averting excess morbidity and mortality associated with such emergencies by promptly taking health services to the most vulnerable and hard-to-reach underserved communities during acute health needs. The usefulness and effectiveness of mobile teams to deliver essential health services to communities that cannot be reached through existing health facilities have been demonstrated elsewhere [20,21]. Despite the challenges in the operating environment, the eMMTs are relatively rapidly deployable and able to respond to many emergencies adequately. However, the scope of the services offered during mobile outreaches lacks critical services for mental and psychosocial disorders. In addition, there is a lack of proper strategy to ensure continuity of services for the patients that would require long-term care and follow up such as patients with chronic conditions like hypertension and asthma. A strategy ensuring children vaccinated during the mobile outreaches receive the subsequent antigens is lacking.

Maximizing the impact of the eMMT strategy requires several actions. First, we recommend expanding the range of services offered by the eMMTs to include psychosocial, gender-based violence (GBV) services and mental health care that is highly beneficial for the conflict-affected populations. Cost-saving strategies and approach should also be incorporated into the intervention to make the intervention more cost-effective. Second, capacity building and collaborating with community health workers, community-based organizations, and local health facilities will ensure the children vaccinated during mobile outreaches receive their age-appropriate subsequent antigens. Third, strengthen the referral network between mobile outreach sites and functional health facilities in the area. Patients with chronic illnesses will need to be linked to health facilities where they will be monitored, and their prescriptions refilled. Fourth, strengthening coordination with local authorities, partners and security apparatus to obtain guidance that will support the planning and execution of activities in a safe environment. Fifth, the adoption of digital health for data capture, reporting, and offering of remote health care services, including training health workers where availability of the internet and power will allow. Finally, the mobile teams should share the data from the mobile clinics with the health facilities serving the catchment populations where they are conducting their outreaches to capture the relevant data by the health facility for their reporting purposes.

Competing interests

The authors declare no competing interests.

Authors' contributions

DD, OPCR, AGG, SM and OOO designed the study, drafted and reviewed the manuscript. DD, OPCR, AGG, JFW, WGWG, TTW, WO, CTY, FBL, JLKJ, ETTO, KKB, SCGA and BAI supported the implementation of the interventions and contributed data on the key achievements attained by the eMMTs. All the authors have read and agreed to the final manuscript.

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Research

Prevalence and factors associated with transmission of lymphatic filariasis in South Sudan: a cross-sectional quantitative study

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Abstract

Introduction: South Sudan is affected by a high burden of Neglected Tropical Diseases (NTDs). The country is very vulnerable to NTDs due to its favourable tropical climate and multiple risk factors. However, the distribution of the diseases and the populations at risk for the various NTDs is unknown. This paper describes the distribution of lymphatic filariasis (LF) in 58 counties of South Sudan.

Methods: a descriptive quantitative cross-sectional study of LF in 58 counties in 8 states of South Sudan recruited adult volunteers aged ≥ 15 years tested for circulating filarial antigens (CFA). A quantitative descriptive statistical was performed to determine the prevalence rates and the endemicity (CFA positivity rate ≥1%) of lymphatic filariasis in 9213 adult individuals from 101 villages.

Results: the overall prevalence of positive CFA was 1.6%, and the highest state prevalence was reported in the Upper Nile state at 3.4%. Based on the prevalence of positive CFA 64% of the surveyed counties are endemic to lymphatic filariasis. The endemicity ranged from 1-11.1% positive CFA. The highest prevalence of positive CAF was observed in the >50 years old age group (2.7%), followed by the 46-50 age group (2.3%). Males tested more positive than females (52.4% Vs 47.6%). Participants were three times more likely to test positive for CFA on filarial test strips (FTS) compared to immunochromatographic test (ICT). There was a statistically significant difference in the prevalence of positive CFA among the two tests (P=.002).

Conclusion: the distribution of LF is widespread, with varying transmission risks. The produced prevalence maps of infection provided evidence on the areas for targeted interventions in the national NTD program in South Sudan. An increased number of positive CFA were identified using FTS than ICT; hence, it is advisable to use FTS in the future transmission survey.

Introduction

Lymphatic filariasis (LF), also known as elephantiasis, is a vector-borne parasitic disease caused by filarial parasites *Wuchereria bancrofti*, *Brugia malayi*, and *B. timori*, which are transmitted from person-to-person by mosquitos in the genera Culex, Anopheles, Mansonia, and Aedes [1-3]. Lymphatic filariasis is one of the preventive chemotherapy Neglected Tropical Diseases (NTDs) [4], which is mainly endemic in the tropics and subtropical areas primarily affecting the poor and marginalized communities. Globally, it is estimated that *Wuchereria bancrofti* causes 91% of LF cases [5]. Once a person is infected, the parasites nest in the lymphatic vessels causing damage, which leads to lymphoedema, elephantiasis of limbs, and hydroceles [6]. The affected persons are often subjected to stigmatization and discrimination [7]. Most infected people do not show any signs or may present with acute filarial episodes. Notably, the risk of developing clinical manifestations decreases with mass drug administration of either ivermectin or diethylcarbamazine in combination with albendazole [5]. An estimated 856 million people who live in 72 endemic countries are at risk of LF, out of which120 million are estimated to be infected with the disease.

Known risk factors for LF include age, sex, non-utilization of insecticide-treated bed nets (ITN), occupation-dependent exposure to mosquitoes such as in farmers, hunters, and source of water [8,9]. South Sudan is very vulnerable to transmission of LF due to high levels of poverty, low literacy rates (27%), and household clustering in the rural, remote and peri-urban settings [10]. These are compounded by an increased likelihood of extreme climatic events such as floods, high temperatures, and moisture conditions, particularly in swampy areas along the Nile River [11]. Information and data on LF in South Sudan are scarce. Anecdotal information suggests that LF may be endemic in all 10 states; however, existing data indicate LF is endemic in three States (i.e. Western Equatoria, Central Equatoria, and parts of East Equatoria) and non-endemic in Northern Bahr el Ghazal and Unity states [12,13]. Although these observations suggested that transmission of LF is ongoing, the actual geographical distribution, extent, and LF prevalence across the country remain unknown. As a response to the resolution at the World Health Assembly (WHA) of 1997 to eliminate LF globally and the control and elimination milestones and target in the WHO 2021-2030 NTD Roadmap, it is imperative to understand the burden of LF in the country for targeted and scaled up interventions [14,15]. Therefore, this study aimed to provide empirical information on the LF prevalence and risk factors associated with LF transmission in South Sudan as observed from LF mapping surveys conducted using Immunochromatographic Test (ICT) and Filarial Test Strip (FTS).

Methods

Study design and area: we conducted a cross-sectional quantitative study using the WHO survey guideline for LF in adults ≥ 15 years of age in South Sudan from 2016 and 2019 [16]. South Sudan is administratively divided into 10 states and three administrative areas, which are further divided into 80 counties, of which 58 had no reliable prevalence data. Due to the prevailing insecurity, the study was conducted in two phases in 2016, phase 1 covering 26 counties and phase 2 in 2019, covering 32 counties.

Study site selection and sample size: a three-stage cluster sampling method drawn from the WHO's Rapid Assessment for Geographical Distribution of Lymphatic Filariasis (RAGFIL) was used [17]. Twenty-two counties, five in Northern Bahr El Ghazal in 2009 (14), eight in Unity, three in Eastern Equatoria, and six in the Central Equatoria States in 2010, with recent LF prevalence data, were identified and excluded from the current study [13]. The 52 counties in the six remaining states, plus Panyijar county from Unity and Kapoeta South, Kapoeta North, Torit, Magwi, and Lapon counties from Eastern Equatoria were included in the study.

The next stage identified the Payams: a Payam is the second-lowest administrative division next to the county using a simple random selection of two villages at least 50 km buffer zone because evidence has shown filariasis foci to be homogenous within a 50 km diameter [18]. Thus, 119 study sites were selected using the lot quality assurance sampling (LQAS) method for a more homogenous population [19]. Individuals who had lived in the village for more than 10 years were selected and tested for W. bancrofti circulating filarial antigen (CFA). The risk of exposure to mosquitoes (host-vector) increased with the number of years resided in the LF endemic areas; hence, WHO guideline-recommended as selection criteria [16]. Exposure to filarial Testing was stopped if two or more people tested positive within each selected village among the first 50 individuals (balanced by gender). Otherwise, testing continued up to 100 individuals. The team sampled adjacent villages if they could not reach this target.

Two key test types were used to rapidly diagnose bancroftian filariasis and its distribution in areas with persistent infections, in 2016 BinaxNOW® Filariasis card test (immunochromatographic card test (ICT) was used, and the Alere Filarial Test Strip (FTS) in 2019. Both Alere FTS and ICT test cards are qualitative point-of-care diagnostic tools that detect *W.bancrofti* CFA in human blood, plasma, or serum [20]. The ICT card test has been used in the Global Program to Eliminate Lymphatic Filariasis (GPELF) since 2000, while the FTS was introduced in 2013 [21]. In both tests, counties were considered endemic if the CFA positivity rate was > 1.0%.

Data collection: nine teams were composed, each comprising a supervisor (i.e. laboratory technologist or an experienced laboratory technician), two laboratory technicians, a data clerk and a social mobilizer. Local health personnel led the study teams to the study areas and assembled community members at either a clinic or health centre for the test, which was convenient for the purpose. Geographical coordinates at each site were taken using smartphones. One millilitre (ml) finger-prick blood was collected from eligible individuals using a heparinized capillary tube and tested for CFA using a rapid ICT card (ICT card, Binax Inc., USA) or the filarial test strip (Alere Filariasis Test Strip). The location, date, name, sex, age and results were entered on the study form on the phone and backed up on a hard copy.

Data analysis: data was captured on Bold Like Us (BLU) studio 5.5 smartphones running Android 4.2 (Jelly Bean) through a modified version of Open Data Kit (ODK) with LINKS application with a server hosted at the national level. The questionnaires and forms collected using ODK in the field were transferred to an aggregate server situated at the national level. Once in the server, an ODK briefcase was used to download data using an export function from the ODK aggregate server (ona.io) while connected to the internet. The questionnaires were downloaded from the Briefcase into Microsoft Excel format for data cleaning and analysis. We conducted a descriptive analysis using IBM Statistical Package for Social Science for Window Version 26.0 (IBM SPSS V26) and produced maps using ArcGIS (ESRI, California, and the USA). The descriptive analysis included socio-demographic characteristics and epidemiological distribution of LF, determination of the proportion of the test result by sex, age group, insecticide-treated bed nets, and test type. For continuous variables like age, we computed mean, median, mode, range and standard deviation; while, for categorical variables such as state, county, gender, age group, and test type, we ran frequency distribution. A two-by-two table was used to determine the relationship between tests types (FTs versus ICT) and test results (positive versus negative), including odds ratio and Pearson´s Chi-Square test. A 95% confidence interval (CI) at α significant level 0.05 was used to reject or accept the null hypothesis based on the calculated significance level and odds ratio.

Ethical consideration: during the survey in 2016/2018 ethical approvals was obtained from the Research and Ethics Committee of the national Ministry of Health. Consent was obtained from all persons examined. All positive cases found during the study were treated with ivermectin 150-200 microgram per kilogram of body weight combined with albendazole 400 milligrams. In the manuscript, secondary data was used with anonymity without ethical clearance.

Results

Study site, study population and prevalence of CFA: a total of 9213 individuals from 101 survey sites located in 58 counties in eight States of South Sudan were tested for CFA and had valid results indicated in Table 1. The age of tested individuals ranged from 15 to 100 years. The mean age was 37 years, with a standard deviation of 14.8 years. The age group that participated the most was 26-30 years (16.8%), followed by those above 50 years (15.9%), who also contributed the highest proportion of positive results (26.3%) (Table 1). Males tested more positive than females (52.4% Vs 47.6%), but there was no statistically significant difference

Table 1: socio-demographic characteristics and epidemiological distribution of the prevalence of positive circulating lymphatic filariasis in South Sudan - 2016 and 2019

Variable	Category	The total number (%) tested positive	The total number (%) tested negative	Total number (%) of test
Age group	15-20	14(1.1%)	1291(98.9%)	1305(14.2%)
	21-25	3(0.30%)	913(99.7%)	916(9.9%)
	26-30	15(1.0%)	1531(99.0%)	1546(16.8%)
	31-35	22(2.1%)	1017(97.9%)	1039(11.3%)
	36-40	24(1.9%)	1234(98.1%)	1258(13.7%)
	41-45	11(1.3%)	862(98.7%)	873(9.5%)
	46-50	19(2.3%)	794(97.7%)	813(8.8%)
	>50	39(2.7%)	1424(97.3%)	1463(15.9%)
Sex	Female	70(1.4%)	4817(98.6%)	4887(53.0%)
	Male	77(1.8%)	4249(98.2%)	4326(47.0%)
State	Eastern Equatoria	10(2.1%)	463(97.9%)	473(5.1%)
	Jonglei	20(0.9%)	2137(99.1%)	2157(23.4%)
	Lakes	7(0.5%)	1395(99.5%)	1402(15.2%)
	Unity	0(0%)	197(100%)	197(2.1%)
	Upper Nile	53(3.4%)	1535(96.6%)	1578(17.1%)
	Warrap	8(0.6%)	1273(99.4%)	1281(13.9%)
	Western Bahr El Ghazal	2(0.3%)	589(99.7%)	591(6.4%)
	Western Equatoria	47(3.1%)	1487(96.9%)	1534(16.7%)
	Total	147 (1.6%)	9076 (98.4%)	9213(100%)

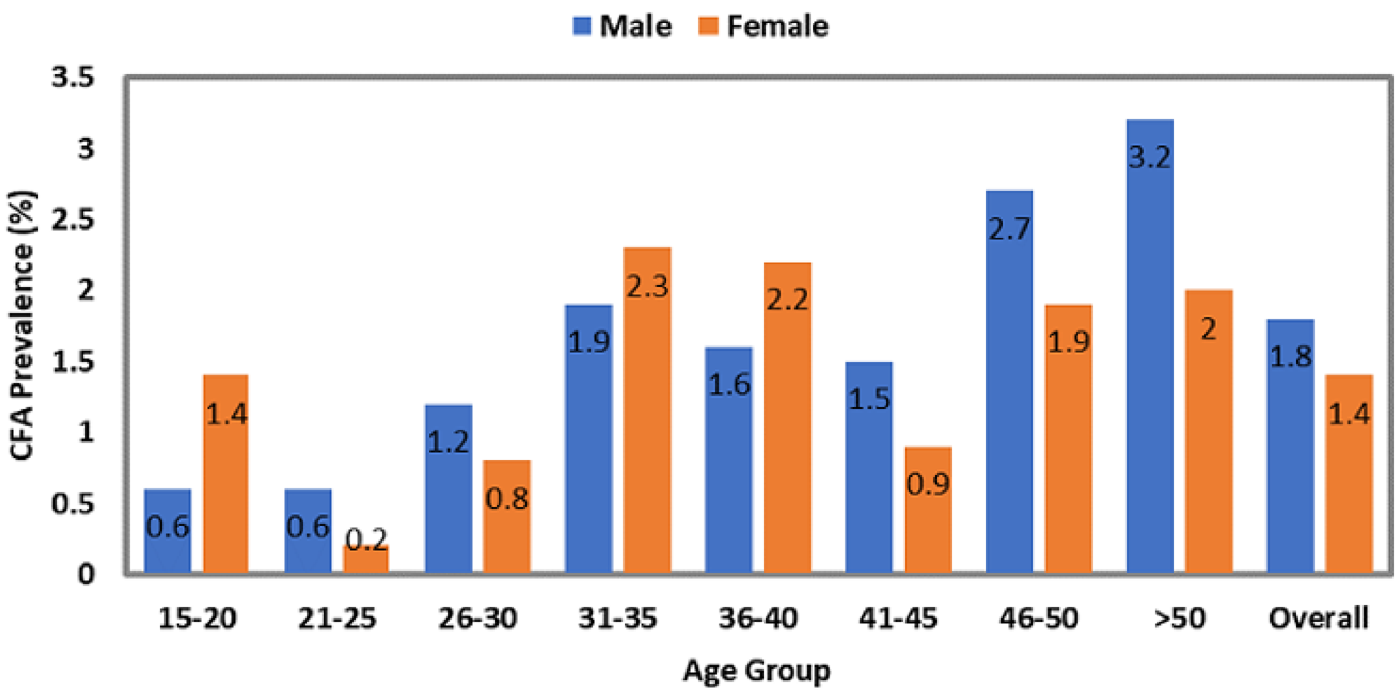

Figure 1: circulating filarial antigen prevalence by sex and age group: study findings of the fieldwork conducted in South Sudan - 2016 and 2019

Table 2: prevalence of positive circulating lymphatic filariasis antigen in South Sudan - 2016 and 2019

Parameters	Positive	Negative	Total	Odds ratio	P-value	95% confidence interval
Male	78	4248	4326			
Female	69	4818	4887	1.28	0.135	0.92, 1.77
Total	147	9066	8213			
Filarial test strips	113	5133	5246			
Immunochromatographic test	34	3933	3967	3.18	0.002	1.46, 6.93
Total	147	9066	9213			

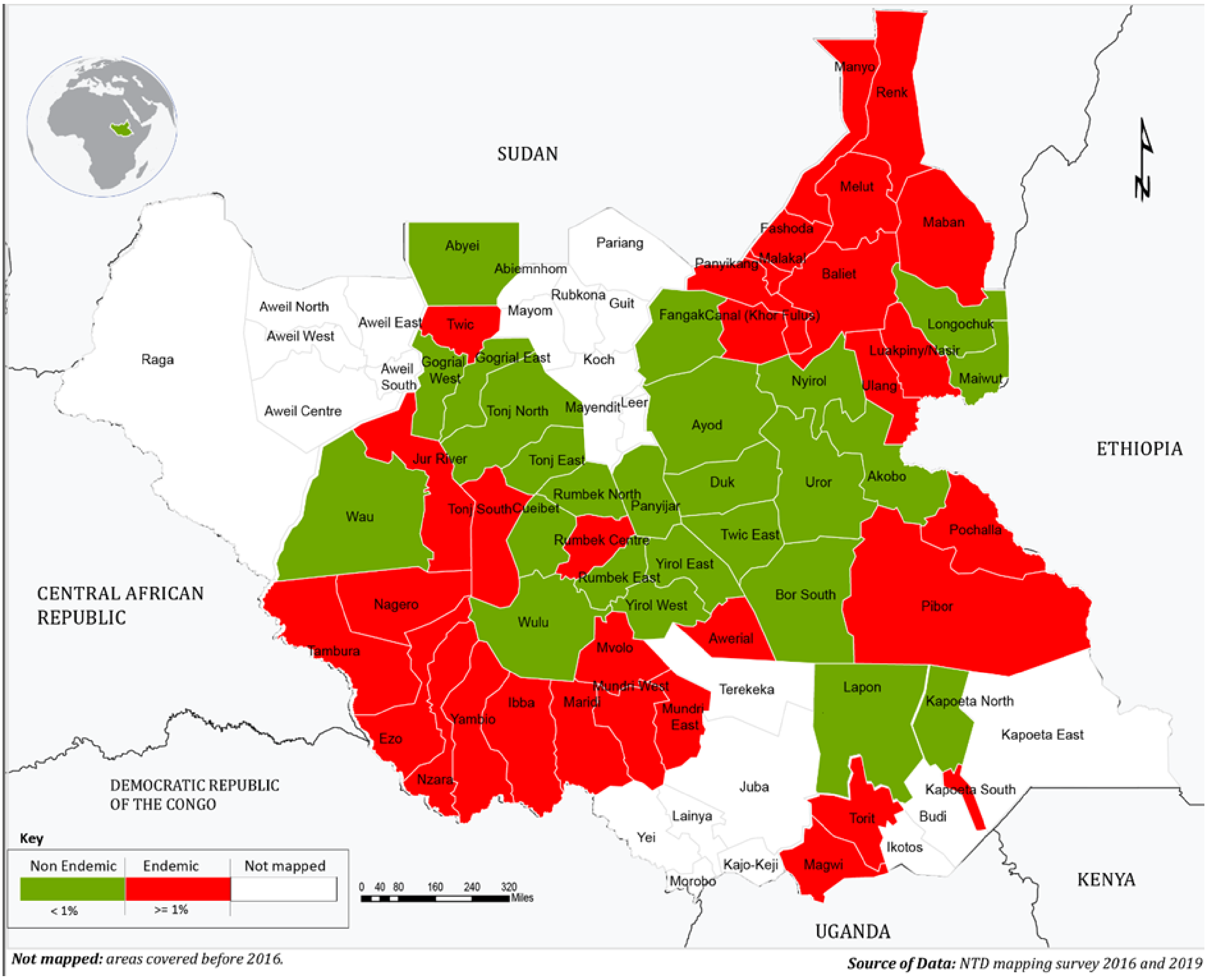

Figure 2: lymphatic filariasis endemicity map South Sudan: study findings of the fieldwork conducted in South Sudan in 2016 and 2019

among gender. Participants were three times more likely to test positive for CFA on filarial test strips (FTS) compared to immunochromatographic test (ICT) (2.2% Vs 0.9%). There was a statistically significant difference in the prevalence of positive CFA among the two tests (P=.002) (Table 2).

The highest number of individuals tested was reported in Jonglei at 23.4 % (2157/9213), followed by Upper Nile (17.1%), Western Equatoria (16.7 %), and Lakes (15.2 %) (Table 1). The overall prevalence of positive CFA was 1.6% representing 1.8% in males and 1.4% in females (Figure 1) and was observed more in the >50 years old age group (2.7%), followed by the 46-50 age group (2.3%). At state level the proportion ranged from 0 to 3.4% (Table 1). The highest proportion of positive cases was seen in Upper Nile (36.1%), Western Equatoria (32.0 %), and Jonglei (13.6%). Out of the 58 counties, 37 (63.7%) were endemic for LF (Figure 2).

All counties in Western Equatoria state endemic while all except one county in Eastern Equatoria (Kapoeta North) and two in Upper Nile (Longochuk and Maiwut) were endemic for LF. The prevalence of positive CFA varied from 0%-11.1% by county with highest being Pibor 11.1%, Renk 9.5%, Tambura 9.2%, Melut 7.2%, Maban 7.2%, Kapoeta South 6.2%, and Khorflus 6.1% (Figure 2). A total of 7,667 (83.2%) surveyed participants resided in the altitude range of 389 meters to 560 meters above sea level, while the remaining 1,551 (16.8%) lived above 560 meters. The prevalence of positive CFA was 1.5% (113/7662) versus 2.2 (34/1551) respectively.

Discussion

This study presents the results of the first community-wide study to elucidate LF prevalence in eight states of South Sudan. The findings show the prevalence of W. bancrofti in the majority of the 58 counties sampled, which confirms the anecdotal evidence that LF is prevalent in all the 10 states of the country [22]. The ongoing transmission is widespread and conforms to previous predictions of LF in South Sudan (21); however, in many of the counties, the prevalence was low. A high prevalence of positive CFA was observed in the areas near national borders in the North-eastern part of the country (i.e. Upper Nile and the Jonglei States) and Western Equatoria State. Upper Nile falls within a region habitually known to be highly endemic. This finding is not surprising as the Blue Nile and the South Kordofan Sudan, which borders the Upper Nile, have a widespread high LF prevalence of more than 50% [23]. At the same time, Jonglei is close to the hyperendemic regions of Gambella and Beni Shangul Gumuz of Ethiopia [24]. While Western Equatoria State borders the highly endemic area of the neighbouring Democratic Republic of Congo (DRC) [25]; an occurrence that could explain the increased prevalence of LF in the counties of the western equatorial state bordering endemic areas of DRC. It is not clear why most of the central part of the country is non-endemic for the disease; perhaps this could be attributed to a less conducive environment for vector breeding which drives the transmission of W. bancrofti. This finding thus needs to be assessed further, including the persistently high prevalence in the other areas.

Both the FTS test and (ICT) test card are qualitative point-of-care diagnostic tools that detect W. bancrofti CFA in human blood, plasma, or serum. The ICT card test has been used in the global program to eliminate lymphatic Filariasis (GPELF) since 2000, while the FTS was introduced in 2013 [21]. Since its introduction FTS test had shown superiority over the ICT card test in terms of both sensitivity and specificity. The study reaffirmed the higher sensitivity and specificity of the FTS test compared ICT card test [20,26]. These findings are similar to a study conducted in Liberia where the detection rate was 26.5% more with FTS than ICT [20,27]. Furthermore, ICT loses its sensitivity in low endemic areas, particularly in individuals exhibiting low CFA levels [26,27]. This raised serious concerns, especially in the counties that were mapped lymphatic filariasis CFA in 2016 using ICT. Due to the significant difference in test sensitivity between the test types used, some of the villages found to be non-endemic could be endemic. Therefore, the national LF programme should implement a more sensitive test to monitor and evaluate the impact of the interventions is highly recommended [28].

An interesting finding from this study is the non-statistically significant higher CFA positivity in males versus females. In most instances, it is believed that males go out to work in the field and have a higher chance of exposure to the bite of parasite carrying mosquito, which shows an increasingly higher infection than females [29]. Moreover, the compelling evidence that women of the reproductive age group bear immunity to LF infection adds to the lower number of positive results observed in females [30,31]. An in-depth analysis of sex differentials in prevalence, density and clinical pathology study revealed a higher prevalence of infection in males than females. However, in South Sudan, several factors equally affect males and females for mosquito bites such as flooding, displacement, and poor socio-economic status [22,32]. These exposures may explain an increased prevalence of LF in males and females without significant sex differentials. Hence, this finding is critical in the elimination programme, ensuring a high treatment coverage in males and females to interrupt transmission.

The older age group mainly affected by LF in South Sudan is consistent with other similar prevalence studies [31]. This can have implications during impact assessment as the focus is on young children for new infections. Inclusion of the older age group in the evaluation may accurately represent the presence or absence of infection. Other studies have shown increasing microfilaria rate in children until the age of 20-30 years, then it remains constant or decreases due to host immunity [6,30]; an observation was also made in our study.

Environmental factors play a critical role in the transmission of LF in communities [33]. High altitude is protective in humans for LF infection due to the constant negative association between vector breeding capacity and increases in altitude as it becomes less suitable for parasite survival. The prevalence of LF in our study is higher at an altitude above 560 meters than an altitude range of 389 to 560 meters (70.7% versus 29.3%) [23]. Of the total surveyed participants, 73% of the surveyed participants resided in the altitude range of 389 to 560 meters above sea level, while the remaining 27% lived above 560 meters. The altitude for South Sudan is low in most parts of the country with the highest altitude of the sites recording positive results in our study was at 780 meters. This is within the favourable altitudes in other countries, ranging from 100 meters to 1600 meters. Hence, the areas included in our study are within the favourable altitude of mosquito breeding and LF transmission.

A significant decline in LF prevalence observed in areas with effective implementation of vector control measures even before community-based mass drug treatments for LF commences assists in controlling and eliminating LF [34]. In most African countries, the malaria vector species also tend to be the principal LF vectors. Where vector control measures are scaled up and sustained, especially under the malaria control programme, there are secondary benefits to the LF programme as a reduction in CFA prevalence is observed [1]. The experts' review of LF elimination highlighted the importance of integrating vector control under malaria control for this purpose [3,5,35]. In 2009, South Sudan scaled up the distribution of ITN as a vector control measure against malaria infection [36]. However, the number of cases continued to increase due to inadequate utilization of the nets and made the population is at very high risk of malaria and LF.

Conclusion

The persistent high prevalence of CFA in South Sudan requires a more substantial move towards an integrated strategy that includes vector control, advocacy and social, behavioural change communication [35,37]. Still, the inadequate data on the exact vector(s) that transmits LF and their distribution across the country may limit the cause-effect and the association to specific vector control measures. The present study has provided new data on the epidemiology of lymphatic filariasis in South Sudan. This new knowledge is useful in the implementation of the GPELF goals which are aimed at stopping the spread of disease and the management of morbidity. In light of the high prevalence of positive CFA in the Upper Nile, Jonglei and Western Equatoria state that share borders with Sudan, Ethiopia and DRC, respectively, the country requires concerted efforts and effective policy to interrupt LF transmission in these areas with a focus on cross-border coordination and synchronization of LF preventive and control interventions. The superior sensitivity of FTS to ICT shown by this study provides evidence for policy recommendations on the type of tests to use for transmission assessment surveys to evaluate the success of LF elimination after mass drug administrations in South Sudan and other similar contexts where more sensitive tests are required. Although our study has generated evidence for a national LF elimination programme, useful information to further improve programme implementation is required. The GPELF recommends mass drug administration (MDA), morbidity management and disability prevention (MMDP) as strategies to achieve LF preventive goals [38]. Our study did not include the search for LF morbidity such as hydrocele, lymphoedema in those who participated in the study; hence, future research should estimate LF morbidity in the country. The NTD programme in the Ministry of Health should also prioritize LF morbidity assessment at every available opportunity. Integrating active case search for hydrocele and lymphedema during the mass drug administration (MDA) and other public health interventions is an option in this regard. Besides, there are still grey areas that require further research, such as the low positive correlation between the LF prevalence and altitude, particularly at the actual site and not at the county level.

What is known about this topic

- Although lymphatic filariasis is endemic in South Sudan, the geographic distribution of the disease is unclear;
- While the general risk factors for transmission of the disease is known, these factors remain unclear in the country;
- The superior sensitivity of filarial test strips over immunochromatographic test in the detection of circulating filarial antigens.

What this study adds

- This study provides information on the prevalence, risk factors, and distribution of in South Sudan;
- Key recommendations for scaling up effective and integrated public health measures for prevention and control of lymphatic filariasis.

Competing interests

The authors declare no competing interests.

Authors' contributions

MNS and KKB conceived and wrote the first draft of the manuscript. KKB and MNS conducted the data analysis. OOO, KKB and MNS provided insights into the study's conceptualisation and conducted an extensive review of all manuscript drafts. All authors read and provided significant inputs into all drafts of the manuscript, agreed to be accountable for all aspects of the work and approved the final draft of the manuscript for publication.

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Research

Assessment of infection prevention and control readiness for Ebola virus and other diseases outbreaks in a humanitarian crisis setting: a cross-sectional study of health facilities in six high-risk States of South Sudan

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Abstract

Introduction: the study was conducted to assess the readiness and capacity of the core components of infection prevention and control and water, sanitation and hygiene in health facilities to effectively contain potential outbreaks of Ebola virus and other diseases in South Sudan.

Methods: it is a descriptive cross-sectional study which was conducted in health facilities in six high-risk States of the country from September 2020 to December 2021. Data was collected using a structured questionnaire and analyzed with Microsoft Excel software.

Results: one hundred and fifty-one (151) health facilities with a total bed capacity of 3089 were enrolled into the study. Overall, the least prepared infection prevention and control, water and sanitation core components in ascending order were the coordination committee structure (13.19%), guidelines and SOPs (21.85%), vector control (22.02%), staff management (30.63%), and training received (33.64%). The best prepared components in descending order were integrated disease surveillance and response capacity (69.83%), medical waste management system (57.12%) and infrastructure compliance (54.69%).

Conclusion: the findings of this study which is comparable to those of other studies in similar settings validates the perception that Infection Prevention and Control/Water, Sanitation, and Hygiene (IPC/WASH) capacity and readiness is inadequate in South Sudan. To scale up these core components, we recommend development and implementation of a comprehensive and long-term infection prevention and control strategic plan as part of the country's broader health sector recovery planning.

Introduction

Infection Prevention and Control (IPC) is aimed at preventing avoidable infection of patients and healthcare workers at health facility and community levels [1]. It is a key determinant of Universal Health Coverage (UHC) and health security [2]. It plays a critical role in preventing antimicrobial resistance in healthcare settings and in preparing health care systems to prevent and respond to current and future infectious disease threats [3]. Core components include standard precaution measures such as hand hygiene, the use of personal protective equipment (PPE) by designated health workers, early detection and isolation of cases of infectious diseases, effective medical waste management, and safe burial [4,5]. Available scientific evidence has identified poor IPC practices as a major driver of transmission of infectious diseases outbreaks, particularly viral hemorrhagic diseases [6]. Unfortunately, such outbreaks often occur in humanitarian settings like South Sudan where the health system is weak, and IPC infrastructure, supplies, staffing, and training are rudimentary [7].

Water, Sanitation, and Hygiene (WASH) plays an essential role in IPC, particularly in healthcare settings. Infection prevention and control and WASH are two sides of the same coin; thus, safe WASH contributes to enhanced IPC, patient, and health workers´ safety, and vice versa [8]. A robust WASH system significantly prevents and controls diseases such as schistosomiasis, trachoma, soil-transmitted helminths, and diarrhea diseases, including cholera [9]. In recent times, both concepts have gained much traction with the emergence and re-emergence of infectious diseases such as Severe Acute Respiratory Syndrome (SARS), COVID-19, Ebola Virus Disease (EVD) and other viral hemorrhagic fevers, which require strong IPC/WASH [10-12] .

South Sudan experiences recurrent incidents of emergencies regularly; a significant number of these emergencies are outbreaks of infectious diseases which often results in high morbidity and mortality. The country's southern parts sit in the ecological zone of the EVD and yellow fever, which is contiguous with the same zone in neighboring Democratic Republic of Congo (DRC) and Uganda [13]. The country also continues to experience repeated outbreaks of other infectious diseases such as Rift Valley fever, measles, cholera, etc. [14-17]. At the onset of the 2018, EVD outbreak in Ituri and North Kivu Provinces of DRC, South Sudan and three other countries that border DRC (Burundi, Rwanda and Uganda) were designated as high-risk for cross border importation of the EVD, which necessitated heightened preparedness activities [18]. Thus, the country implemented various EVD preparedness interventions from August 2018 to December 2019 [19]. The COVID-19 outbreak in Wuhan, China, in December 2019 further dictated sustained preparedness and response interventions for infectious diseases in the country. The country recorded its first case of COVID-19 on April 5, 2020 and thus moved from the preparedness to response phase, further requiring a strong outbreak prevention and control system [20].

South Sudan scaled up IPC/WASH interventions due to the increasing threats of disease outbreaks, however, there is a paucity of reliable data on the status of IPC/WASH interventions in the country. This is a major constraint to evidence-based prioritization, planning, implementation and monitoring of IPC/WASH interventions. Thus, IPC interventions are often ad-hoc rather than proactive and systematic. Furthermore, the technical knowledge and capacities of national and international agencies involved in implementing IPC/WASH interventions in the country are often weak, affecting both the quantity and quality of interventions. Given the exposure of South Sudan to threats of cross border importation of EVD, recurrent outbreaks of infectious diseases and the ongoing COVID-19 outbreak, which require effective IPC/WASH interventions for prevention and control, the importance of having reliable data for evidence-based planning, implementation and monitoring of interventions cannot be overemphasized. An IPC/WASH study was thus conducted in selected health care facilities in the country.

The objective of the study were to assess the readiness and capacity of the core components of IPC/WASH in health facilities to effectively respond to and contain potential outbreaks of EVD and control the ongoing COVID-19 outbreak in the country and to establish baseline information for planning, implementation, supervision, monitoring, and evaluation of short- and long-term IPC/WASH interventions. The study also sought to raise awareness about and provide evidence for advocating for more investments in IPC/WASH in the country. In this research article, we present and discuss the key findings, conclusions, and recommendations of the study.

Annex 1: survey questionnaire							
WASH FIT - WASH IN HEALTH FACILITY ASSESSMENT TOOL							
Name of project			**Initial comments on this evaluation**				
Name of the health structure							
Name of the evaluator							
Date							
Time							
GPS coordinate							
Facility inpatient bed capacity							
		Ranking					
1.IPC WASH COMMITTEE STRUCTURE	**0% Not available**	**25% Below standard**	**50% Acceptable Standard**	**100% Meet full requirements**	**Score**	**Reason of not achieving the set standards & Indicators**	**Corrective measures technical recommendation**
Does the IPC committee include both doctors/clinicians, nurses, PHO, lab tech and hospital admin in charge?							
Does the IPC committee have a weekly meeting to discuss IPC issues of the facility?							
Are senior facility leadership part of the IPC committee?							

Methods

Study design and sampling method: a descriptive cross-sectional study on the capacity and readiness of the core components of IPC/WASH to respond to infectious disease outbreaks was conducted in health facilities in six high-risk States of South Sudan from February 2020 to December 2021. The three Equatoria States were initially enrolled into the study in 2020. With the report of the first case of COVID-19 in the country on April 5, 2021 and subsequent declaration of an outbreak, three more States, namely, Western Bahr el Ghazal, Lakes and Jonglei, classified as high risk for both EVD and COVID-19 transmission, were enrolled into the study. A purposive sampling method was used to identify between 14 to 16 health facilities per State. Inclusion criteria were any operational health facility with permanent structures and at least two or more healthcare workers.

Study setting: South Sudan, a country experiencing a chronic humanitarian crisis, is bordered by Uganda in the South, DRC in the South West, Central Africa Republic in the West, Sudan in the North, Ethiopia in the East and Kenya in the Southeast. These borders are porous with free population movements between the neighboring countries for economic and sociocultural reasons. The country has a 2021 population of 11.4 million and landmass of 619,745 km2 [21]. It is divided into ten States and three administrative areas which are grouped into the three historical Provinces namely Bahr el Ghazal, Equatoria and Greater Upper Nile. Equatoria is in the southern part of the country and is sub-divided into three States namely Central, Eastern and Western Equatoria. Equatoria shares borders with Uganda and DRC; thus, it is classified as high-risk for cross border transmission of EVD outbreaks. Western Bahr el Ghazal, Lakes and Jonglei States share borders with Equatoria Province in their southern parts and are also classified as high-risk for EVD transmission. As of the time of this study, all six States had recorded cases of COVID-19 which further justified their inclusion in the study. Healthcare delivery in South Sudan is through a network of Primary Health Care Units (PHCUs), Primary Health Care Centres (PHCCs), County (General) and State referral hospitals at the formal level while informal health services are delivered through the Boma Health Initiative at the community level. Oversight for the healthcare system of the country is provided by the State and National Ministries of Health.

Data collection: quantitative data was collected using a structured questionnaire (Annex 1) adapted from the WHO guidelines on core components of IPC programmes at the national and acute health care facility levels [2] and Water and Sanitation for Health Facility Improvement Tool (WASH FIT) [9] both of which represent the minimum requirements for IPC/WASH in health facilities. The questionnaire contained 112 questions grouped into twelve sections that reflect the IPC core components and WASH in health facility minimum requirements (Table 1). Data was collected by six IPC/WASH experts from WHO and the Ministry of Health. Before the commencement of data collection, the data collectors were trained on the study objectives, methods, and the data collection tool. The questionnaire was pre-tested by the data collectors and revised accordingly before deployment and commencement of actual data collection. In each health facility, the data collectors introduced

Table 1: infection prevention and control/water, sanitation, and hygiene (IPC/WASH) core components, criteria for assessment and scorecard

Core component/Indicator assessed	Criteria for assessment	Scorecard
Hygiene and sanitation	Twenty-four (24) questions to assess the cleaning procedures, availability of latrines, handwashing, shower, washing and drainage facilities	0%: not available (the IPC/WASH core component has not been implemented)
Integrated Disease Surveillance and Response (IDSR) capacity	Seven (7) questions to measure capacity of health facility to conduct IDSR	25%: basic (some core components of IPC/WASH are available but not sufficient; further improvement is required)
Infrastructure compliance	Nine (9) questions assessing compliance of health facility infrastructure with IPC/WASH guidelines and Standard Operating Procedures (SOPs)	50%: intermediate (most core components of IPC/WASH are available and appropriately implemented. The facility should continue to improve the scope and quality of implementation and focus on the development of long-term plans to sustain and further promote the existing IPC/WASH core functions)
Medical waste management system	Twenty (20) questions assessing capacity for management of sharp, soft contaminated, organic, and hazardous waste	100%: advanced: (IPC/WASH core components are fully available and implemented according to the WHO recommendations and appropriate for the needs of the facility)
Staff management	Six (6) questions to assess availability, training and job description of IPC/WASH staffing in the health facility	
Type of training received	Seven (7) questions assess IPC/WASH training of healthcare workers	
Vector control	Four (4) questions to measure the implementation of key vector control interventions such as indoor residual spraying, use of bed nets and window screens for control of mosquitos	
Quantity of water supply	Ten (10) questions to assess the quantity and quality of water supply to the health facility	
IPC/WASH guidelines and SOPs	Three (3) questions to assess availability and use of IPC/WASH guidelines and SOPs	
IPC/WASH committee structure	Nine (9) questions to assess the availability, functionality, objectives, and funding of IPC/WASH committees	
IPC/WASH supplies	Eight (8) questions to assess the availability of IPC/WASH supplies such as soap, hand sanitizer, light personal protective equipment and post-exposure prevention kits	

themselves and explained the study objectives and data collection mechanism to the head of the facility. The questionnaire was then administered to either the head of the health facility or the officer in charge of IPC/WASH. A physical assessment of the facility was conducted to verify the responses to the questionnaire. Global Positioning System (GPS) coordinate of each health facility was obtained and recorded on the questionnaire to facilitate mapping.

Data analyses: the data was cleaned, entered and analyzed with Microsoft Excel software. Twelve indicators identified based on expert consensus were analyzed (Table 1). The average score of the response for each indicator was calculated and tabulated by State. Based on the overall score achieved in the twelve indicators, each State was assigned to one of four IPC/WASH status levels: not available, basic, intermediate, and advanced (Table 1). A score of 50% and above is considered acceptable within the context of South Sudan. The frequency distribution of the assessed health facilities was calculated and tabulated.

Ethical clearance and approval: administrative clearance for this study was provided by the Ministry of Health of South Sudan. World Health Organization provided the ethical clearance (WHO e-Pub no: ePub-IP-00331783-EC).

Results

One hundred and fifty-one (151) health facilities with a total bed capacity of 3089 in six States were enrolled into the study. Almost half (49%) of the surveyed health facilities were PHCCs while the rest were PHCUs (25%) and hospitals (14.51%) (Table 2). Western Equatoria State (34.45%) was the least prepared State followed by Eastern Equatoria (43.94%) and Central Equatoria (45.54%) (Figure 1). Overall, the least prepared IPC/WASH core components in ascending order were the IPC/WASH committee structure (13.19%), IPC/WASH guidelines and SOPs (21.85%), vector control (22.02%), IPC/WASH staff management (30.63) and IPC/WASH training received (33.64%) (Figure 2). The best prepared components in descending order were IDSR capacity (69.83%), medical waste management system (57.12%) and infrastructure compliance (54.69%) (Figure 2). The IPC/WASH committee structures, guidelines and SOPs were generally poor across all the six States (Table 3). Western Equatoria State scored very low in IPC/WASH committee structures (8.39%), guidelines and SOPs (11.42%), IPC/WASH staff management (18.87%) and vector control (19.40%) (Table 3). Eastern Equatoria State scored very low in vector control (3.44%) and IPC/WASH committee structure (18.33%) while Lakes State scored very low in IPC/WASH training received. Jonglei State scored very low in IPC/WASH committee structure (4.17%) (Table 3).

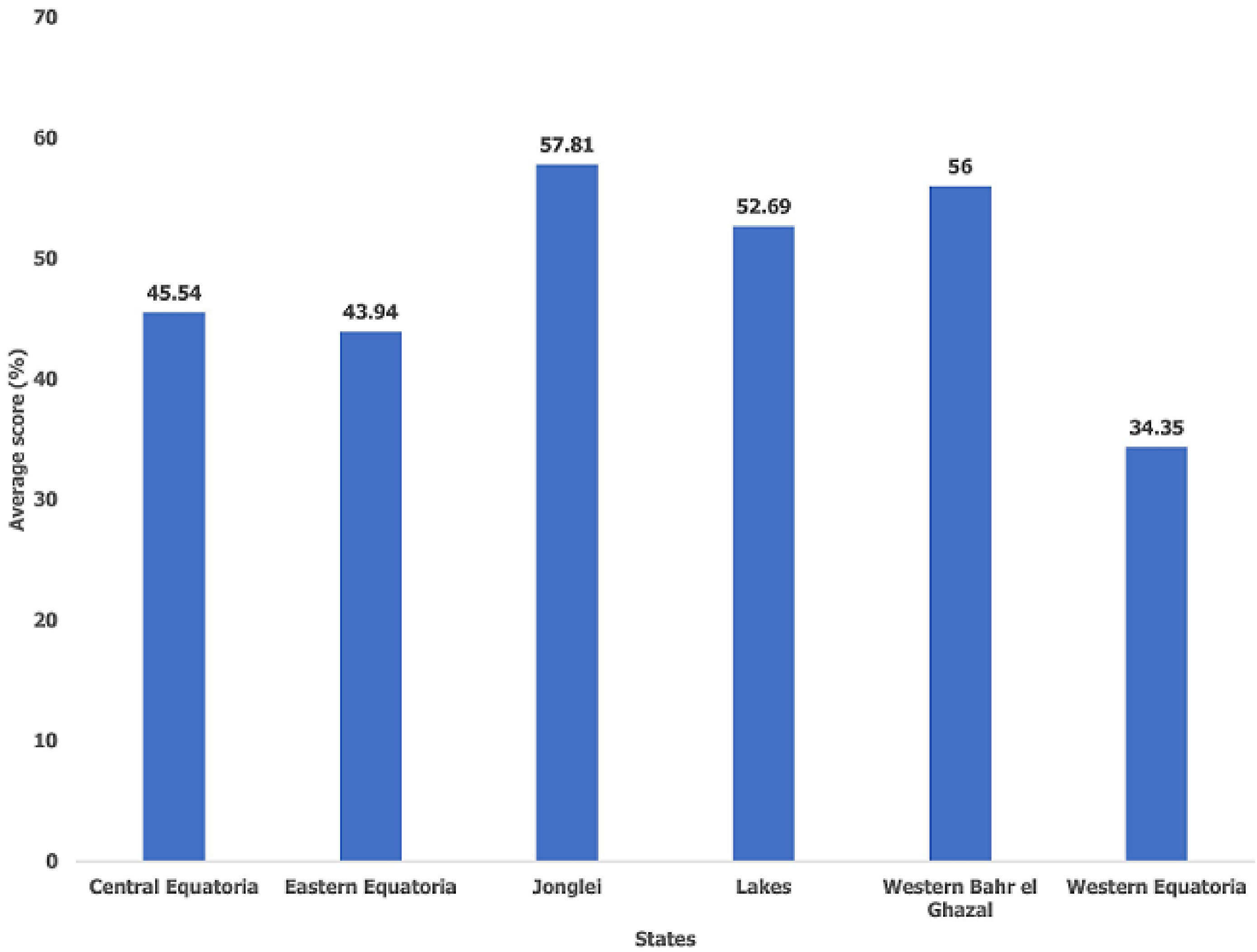

Figure 1: average score of infection prevention and control/water, sanitation, and hygiene (IPC/WASH) readiness in South Sudan by State - December 2021

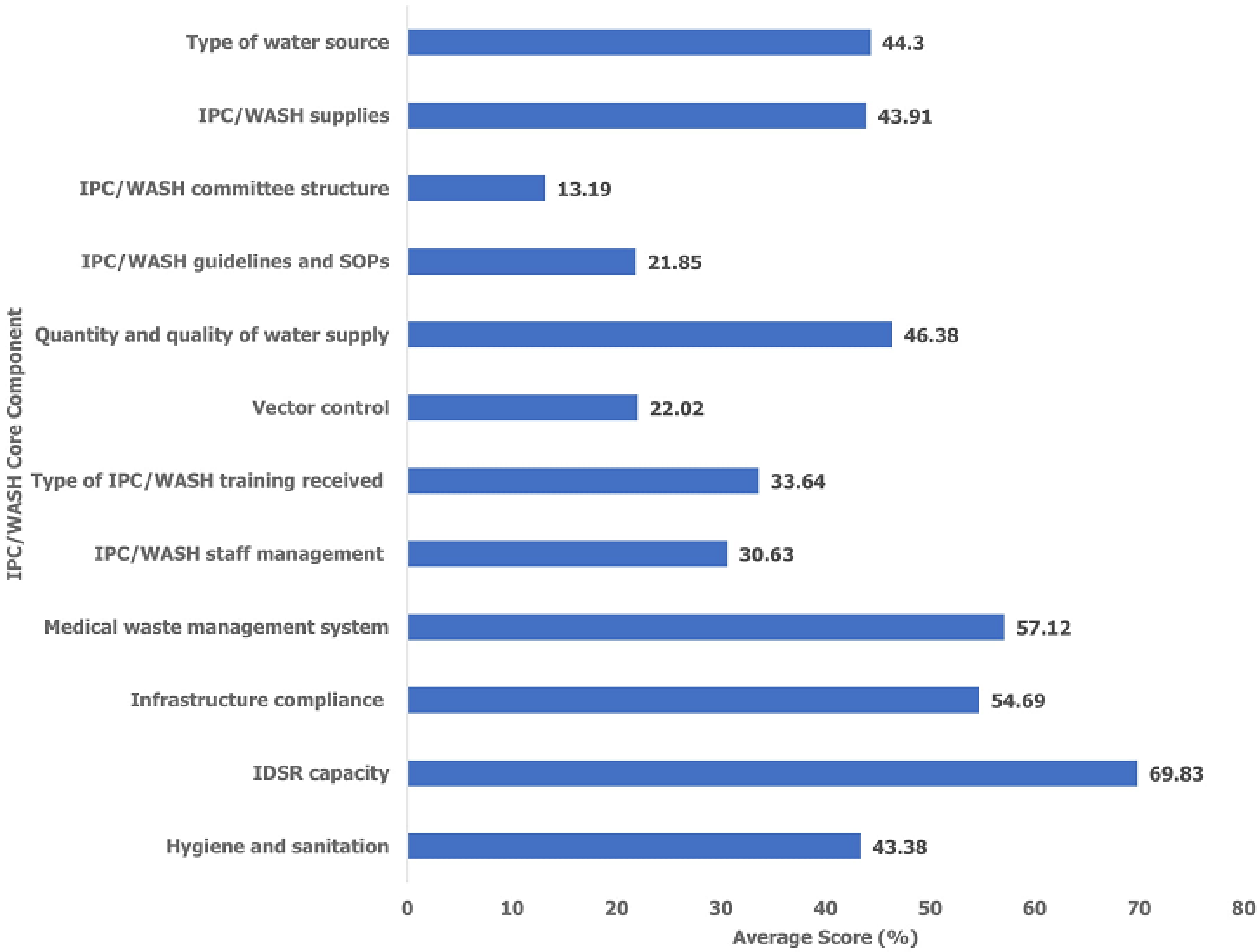

Figure 2: average score of infection prevention and control/water, sanitation, and hygiene (IPC/WASH) readiness by core component in South Sudan - December 2021

Table 2: summary of health facilities assessed by State

State	Total no. of health facilities assessed	Total no. of beds	Type of facilities			
			PHCU	PHCC	Hospital	Others
Central Equatoria	48	1563	3	25	9	11
Eastern Equatoria	20	165	8	9	2	1
Jonglei	6	282	0	3	1	2
Lakes	7	321	0	5	1	1
Western Bahr el Ghazal	16	486	0	11	5	0
Western Equatoria	54	272	27	21	4	2
Total	151	3089	38	74	22	17

Table 3: average score of infection prevention and control/water, sanitation, and hygiene (IPC/WASH) readiness by core component and State of South Sudan - December 2021

IPC/WASH core component (%)	State					
	Central Equatoria	Eastern Equatoria	Jonglei	Lakes	Western Bahr el Ghazal	Western Equatoria
Hygiene and sanitation	48.64	40.83	64.93	53.87	52.89	30.71
IDSR capacity	51.50	76.96	95.24	77.55	90.40	70.17
Infrastructure compliance	66.8	52.92	62.5	57.54	58.16	41.72
Medical waste management system	56.84	52.31	88.54	66.07	82.13	46.06
IPC/WASH staff management	33.85	44.79	40.28	38.10	34.38	18.87
Type of IPC/WASH training received	40.40	50.54	21.43	1.53	17.44	31.70
Vector control	25.79	3.44	54.17	27.68	27.38	19.40
Quantity and quality of water supply	50.16	33	44.17	64.64	62.97	40.08
IPC/WASH guidelines and SOPs	20.83	33.37	16.67	51.19	34.38	11.42
IPC/WASH committee structure	14.06	18.33	4.17	19.44	21.01	8.39
IPC/WASH supplies	44.33	45.94	65.10	70.54	69.34	28.56
Type of water source	41.98	56	51.67	45	57.81	34.90

Discussion

This study sought to establish the capacity and readiness of the core components of IPC/WASH in health facilities to prepare for and respond to disease outbreaks and enhance the safety of patients and health workers in South Sudan. To the best of our knowledge which is based on an exhaustive literature review, it is the first documented study that comprehensively assessed the status of IPC/WASH in health facilities in the country thus, its findings will form the baseline for planning, supervision, monitoring, and evaluation of IPC/WASH interventions moving forward. The findings showed a lack of readiness of most IPC/WASH components to prevent disease outbreaks except for IDSR capacity, infrastructure compliance and medical waste management system. There was a generally poor readiness of IPC/WASH committee structure, vector control and IPC/WASH supplies components across most of the study area. The study showed weak IPC readiness in the three Equatoria States which had the highest risk for EVD transmission.

The general lack of readiness of most IPC/WASH components that were observed in this study is similar to the findings of Lowe *et al.* in their study of IPC in eight conflict-affected countries [22] and those of Pathmanathan *et al.* and Fofanah *et al.* in Sierra Leone [23,24]. This trend may be attributed to several reasons. Due to several years of war, a chronic humanitarian crisis and neglect, the health system of South Sudan is chronically weak and barely able to support good quality healthcare services, including IPC/WASH. For instance, gross underfunding with less than 3% of the country´s Gross Domestic Product allocated to the health sector annually is inadequate to finance the delivery of good quality health care services [25]. Likewise, the dearth of healthcare workers, weak supply chain management system for essential medicines and medical supplies and inadequate service delivery also constrain delivery of essential IPC/WASH interventions. The civil conflicts of 2013/2014 and 2016 contributed to further decimation of an already weak health system thus resulting in an acute on chronic problem. Lack of access to several parts of the country for long periods due to insecurity, harsh terrain and natural disasters such as flooding often disrupts the delivery of essential medical supplies and healthcare services, including IPC/WASH. In addition, the concept of IPC/WASH in healthcare facilities is relatively new to the country which may account for limited knowledge and skills of healthcare managers and workers on organizing it. Furthermore, lack of a comprehensive national IPC/WASH strategic plan due to lack of evidence-based information, poor coordination and inadequate oversight of IPC/WASH intervention perhaps are the most critical challenges of IPC/WASH in the country, which is similar to the findings of Cooper *et al.* in Liberia [26].

The high scores observed in the IDSR capacity, infrastructure compliance and medical waste management system components may be associated with ongoing health interventions before and during the study period. As part of efforts to respond to the chronic humanitarian crisis in the country, humanitarian partners led by WHO made massive investments in an Early Warning Alert and Response System (EWARS) to address the need for good quality and real-time data for timely detection and response to epidemics. The EWARS built a foundation for improving disease surveillance which resulted in significant improvements in IDSR capacity all over the country [27]. Similarly, an ongoing EVD preparedness programme to the tune of USD 30.5 million at the time of the study resulted in investments in several components of IPC/WASH [28]. For instance, the four EVD isolation units built and major infrastructural improvements made in several healthcare facilities in the three Equatoria States could have accounted for the high score observed in the infrastructural compliance component. Although the medical waste management component had an acceptable score, we observed lack of materials and systems to enhance proper waste segregation at points of generation, inadequate numbers of standard high temperature incinerators and properly designated waste management areas for effective infectious waste treatment and final disposal in many of the health facilities. These are required for the management of hazardous medical wastes and are thus critical gaps which need to be addressed to improve IPC/WASH in the country moving forward. These findings are similar to those of Lowe *et al.* and Forrester *et al.* in their assessment of IPC in Liberia [22,29].

The IPC/WASH committee structure which requires minimum funding and efforts to implement was the weakest among all the IPC/WASH components which is corroborated by the findings of Tartari *et al.* which showed that low income countries were less likely to have functional IPC/WASH programmes [30]. This finding is perhaps due to the fact that that most of the health facilities in the country lack the required staffing strength in terms of quantity, cadre and quality to constitute the required IPC/WASH committees which is the same as the findings of Fofanah *et al.* in Sierra Leone [24]. Inadequate understanding of and lack of capacity for health coordination at the subnational level may have also constrained the establishment of these committees and their proper functioning. Furthermore, inadequate knowledge of international IPC/WASH norms, standards and guidelines may also contribute to the poor functionality of these committees.

The below average score observed in the vector control component across all the States points to gaps in the malaria control programme, which is primarily responsible for this component hence the need for strengthening the national malaria prevention and control programmes and ensuring greater coordination and collaboration between it and the the IPC/WASH programme at all levels. Although similar to the findings of another study conducted in Uganda [31], the below average score observed in the IPC/WASH supplies component in the three Equatoria States despite an ongoing EVD preparedness programme with a huge procurement component of IPC/WASH supplies is surprising. The same trend was also observed in the IPC/WASH guidelines and SOPs component across all the States except for Lakes. These findings may be attributed to poor coordination, duplication of efforts and inadequate access which were challenges which were earlier described by Olu *et al.* [19].

Limitations: the above findings should be interpreted within the context of three key limitations. Only six and seven health facilities were sampled in Jonglei and Lakes States due to access constraint. Given this small sample size, the findings in both States may not be a true reflection of the IPC/WASH readiness. The purposive sampling method used may have resulted in selection bias in which the more readily accessible and possibly the most functional and good performing health facilities were selected. Lastly, the involvement of some Ministry of Health IPC/WASH officials in the data collection process may have introduced interviewer bias. The data collectors may have focused on their predetermined perceptions which may affect their assessment of the various components of IPC/WASH. This bias was addressed by rigorous screening, selection, training and supervision of the data collectors and physical verification of the responses.

Conclusion

The findings of this study which is comparable to those of other studies in similar settings validates the perception that IPC/WASH capacity and readiness is inadequate in South Sudan. This observation is confounded by the fact that the massive IPC/WASH investments made during the EVD preparedness programme of 2018 to 2020 and the ongoing COVID-19 response programme seem not to have yielded the anticipated outcomes. The inadequate capacity and readiness of the IPC/WASH programme observed in this study are mainly due to the chronically weak health system, lack of a comprehensive national IPC/WASH strategy and inadequate knowledge and funding of IPC/WASH interventions in the country. Other factors include weak capacity for IPC/WASH planning, implementation, supervision, monitoring and evaluation in the country. Furthermore, most of the international IPC/WASH norms and standards may not be realistic in view of the peculiar context of South Sudan.
Moving forward, we propose four main recommendations based on our findings. First, the results of this study should be used to develop and implement a long-term IPC/WASH strategic plan for the country as part of the broader health sector strategic, health system recovery and annual humanitarian response planning. This strategic plan should have a clear monitoring and evaluation framework based on the baseline established by this study and should be actualized through annual IPC/WASH operational plans. Second, the study results should be used to scale up advocacy and resources mobilization for IPC/WASH in the country. Third, international IPC/WASH norms, standards and guidelines should be adapted to suit the South Sudan context. For instance, it may be practically impossible to constitute IPC/WASH committees in every health facilities due to inadequate staffing hence the need to innovate. Fourth, establishment of national and State level platforms for IPC/WASH coordination is critical to coordinate and monitor progress.

What is known about this topic

- Infection prevention and control/water, sanitation, and hygiene (IPC/WASH) is a critical component of outbreak preparedness, response, prevention and control in humanitarian settings such as South Sudan;
- There is inadequate evidence-based information for the planning, implementation, supervision, monitoring and evaluation of IPC/WASH interventions in the country;
- Despite the exposure of the country to threats of disease outbreaks, the readiness of the IPC/WASH programme to adequately respond to these outbreaks is unknown.

What this study adds

- This study identifies the key gaps in the readiness and capacity of IPC/WASH programme in the country to prevent and control diseases outbreaks;
- The study further provides baseline information for future planning, supervision, monitoring and evaluation of IPC/WASH interventions at health facility level.

Competing interests

The authors declare no competing interests.

Authors' contributions

AYSF, AGG, AAUA and NAJA conceived and conducted the study. TDKO and KKB conducted the data analyses. OOO, AYSF and SM wrote all the drafts of the manuscript. All authors read and provided significant inputs into all drafts of the manuscript, agreed to be accountable for all aspects of the work and approved the final draft of the manuscript for publication.

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Research

Acute flaccid paralysis surveillance performance from 2011 to 2020 in Jonglei State, South Sudan: progress and challenges encountered

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Abstract

Introduction: South Sudan reported the last indigenous wild poliovirus (WPV) in 2001 in Unity State, while the country was part of Sudan. In addition, the country reported an imported case of WPV in 2004-2005 and 2008-2009. The WPV circulation in the state was interrupted in 2009 and the last case was reported in Ayod county. The country continues to be at risk of importation of circulating vaccine-derived poliovirus type 2 (cVDPV2). In 2014 and 2020 the country experienced an outbreak of cVDPV2, in which Jonglei state was one of the affected states. Four out of 50 (8%) cVDPV2 cases in 2020 were reported from Jonglei State. The purpose of this study is to review surveillance performance indicators of Jonglei and compare them with the WHO surveillance performance standard and other country´s surveillance performances.

Methods: retrospective secondary data analysis was conducted using the Jonglei state Acute Flaccid Paralysis (AFP) surveillance case-based database from 2011 to 2020. The reason for selecting Jonglei is because it is one of the poor performing states and is chronically hit by flood and internal conflicts. Data analyses were carried out using the Microsoft Excel (2016) program, where descriptive analysis frequencies, tables, and graphs were generated.

Results: the study revealed that 346 AFP cases were reported in the counties of Jonglei state from 2011 through 2020. Out of 11 counties, 11 (100%) of them have reported suspected AFP cases. Children under five years accounted for 275 (79%) of all cases. The male gender accounted for 175 (51%) of all cases. A total of 249 (72%) had received three or more doses of Oral Polio Vaccine (OPV). Non-Polio Acute Flaccid Paralysis (NPAFP) rate varies from 1.2 in 2014 to 4.4 cases per 100,000 children under 15 years in 2018. The stool adequacy ranges from 58% in 2020 to 100% in 2011.

Conclusion: the performance of Jonglei´s AFP surveillance system did not meet the WHO recommended target for both major AFP surveillance indicators (non-polio AFP rate and stool adequacy) during the study period.

Introduction

Poliomyelitis, commonly known as polio, is a disease caused by the poliovirus. It is a paralytic illness with a permanent disability. The disease primarily affects children under five years [1,2]. In May 1988, the forty-first World Health Assembly (WHA) resolved to eradicate poliovirus. The resolution gave birth to the Global Polio Eradication Initiative (GPEI). It is one of the most extensive public health interventions in the history of disease eradication. The program is mainly led by national governments in partnership with the World Health Organization (WHO), United States Centers for Disease Control and Prevention (US CDC), among others [3,4]. Since its commencement in 1988, the GPEI has made enormous progress with an over 99% reduction in global polio cases [5,6]. The GPEI has four strategies for Polio eradication: 1) strong routine immunization with the oral polio vaccine (OPV); 2) supplementary, additional doses of OPV countrywide during National Immunization Days (NIDs); 3) mop-up campaigns in the inaccessible and low immunization coverage areas; and 4) enhance Acute Flaccid Paralysis (AFP) surveillance and report. Acute Flaccid Paralysis surveillance is a key strategy for monitoring the progress of polio eradication [7]. A well-functioning AFP surveillance network offers knowledge for the preparation, execution, control, and provide evidence of eradication or absence of circulation of the disease. Acute Flaccid Paralysis surveillance remains the "gold standard" for detecting the transmission of poliovirus [7-9].

Polio eradication activities in South Sudan started in 1998 in collaborating with WHO and Organization Liberation Sudan (OLS) when the country was part of Sudan. Polio eradication activities were incorporated in the Sudan polio program until South Sudan officially moved to the African Region in October 2013 [10]. South Sudan reported the last indigenous wild poliovirus (WPV) in 2001 in Unity State, while the country was part of Sudan. In addition, the country reported two importations of WPV in 2004-2005 and 2008-2009. The 2008 -2009, outbreak resulted in a total of 64 imported cases (24 cases in 2008 and 40 cases in 2009) and spread to all states of the country except Western Bahr Ghazal. The country remained free from the wild poliovirus since June 2009 [11]. The country continues to be at risk of importation of the circulating vaccine-derived poliovirus type 2 (cVDPV2) with an outbreak of cVDPV occurring in 2014, 2015, and 2020. A total of 50 AFP cases were confirmed for the cVDPV2 with 4 from Jonglei state [12]. The study described the characteristics of reported AFP cases in the last ten years (2011 to 2020). In addition, the study evaluated surveillance performance using the WHO and nationally recommended surveillance standards and recorded lessons and challenges.

Methods

Study area: Jonglei state is one of the ten states in South Sudan. It is the largest state in the country, occupying a land area of 123,070 km^2. The estimated total population is 2.2 million according to the National Bureau of Statistics census 2008 projection. The state lies between longitudes 28 and 30° East, and latitudes 7 and 9 degrees North. Its altitude ranges between 428 and 456 meters above sea level. It comprises 11 counties, 72 Payams, and 343 Bomas.

Selection of study area: Jonglei is one of the former three conflict-affected states and least developed states with poor infrastructure. Access within and outside of states by road is impossible due to flooding, insecurity, and poor road structure. During the rainy season, access is possible using air transport or boats. More importantly, the state is chronically poor performing in the early detection of cases. In this regard, the author's raised a concern and aimed to analyze the surveillance performance and compare it with WHO surveillance performance indicators and other countries.

Study design: a cross-section retrospective study design was used to describe the implementation of acute flaccid paralysis surveillance from 2011 to 2020.

Study population: the target population for this study is children below 15 years of age with sudden onset of weakness or floppiness in one or more limbs regardless of the cause and any person above 15 years old that a physician suspects polio.

Stool sample collection and packaging: two stool specimens of 8-10 grams (size of two adult thumbnails) were collected from AFP suspected cases within 48 hours. The specimens were stored in tightly closed containers and placed in a cold box at 2-8°C).

Laboratory method: two stool samples were collected from AFP cases and transported to a WHO accredited laboratory in Uganda, while the national guideline and protocol for sample transportation and testing strictly followed.

Data collection and analysis: we used the case-based and surveillance line-list data from 2011-2020, which was entered into MS-Excel, where all descriptive analysis frequencies, tables, and graphs were generated.

Definition of terms (the definitions are extracted from the Global Polio Eradication Initiative document)

Suspected AFP: "any child below 15 years of age with sudden onset of weakness or floppiness in one or more limbs regardless of the cause and any person above 15 years old that a physician suspects polio".

Confirmed polio case: "a suspected case with isolation of WPV or VDPV in stool specimens collected from the suspected case or close contact".

Non-polio AFP (NPAFP) case: discarded cases or all AFP cases excluding WPV, cVPDV2, and compatible cases.

Non-polio AFP rate: "number of discarded as NPAFP in children <15 years of age/number of children aged < 15 years x 100,000 per year".

Inadequate case: "late stool collected >14 days from onset of paralysis or collected stool sample arrived at polio laboratory in bad condition".

Stool adequacy rate: "the number of AFP cases with two stools collected ≤14 days after paralysis of onset, two stool samples collected ≥ 24-48 hours apart, and in "good condition divided by a total number of AFP cases, and multiplied by 100".

Compatible case: "a suspected case with no adequate specimens and no isolation of WPV or VDPV from the case or close contacts; and residual paralysis revealed after 60 days follow up. The expert review committee classified as compatible cases due to lack of sufficient clinical and epidemiological data to rule it out polio".

Discarded case: "a suspected case that was adequately investigated (including the collection of adequate stool specimens) and resulted in any of the following: no laboratory evidence of WPV or VDPV infection, inadequate specimens collected and resolution of weakness within 60 days of paralysis onset, deemed by the national expert review committee to not be compatible with poliomyelitis".

Ethical consideration: ethical approval was obtained from the Research and Ethics Committee of the national Ministry of Health to use the secondary anonymized data in the analysis. Confidentiality was ensured as the line list was anonymized, and data protection measures were employed to ensure the security of the data. Administrative clearance for publication of this editorial was provided by the Ministry of Health of South Sudan and WHO (WHO e-ePub-IP-00331568-EC to publish the result. Moreover, the Research Ethics Review Board of the Ministry of Health provided clearance for the publication of the Manuscript (MoH/RERB/D.03/2022).

Results

From 2011 to 2020 during the study period, 346 AFP cases were reported in the 11 counties of Jonglei state. The number of cases reported by year varied from 10 in 2014 to 50 in 2020. Most of the reported cases were children under five years, which accounted for 275 (79%) of all cases. Males accounted for 175 (51%) of cases. Fever at the onset of paralysis was recorded in 325 (94%) and asymmetric paralysis in 226 (65%) of all reported AFP cases (Table 1). The non-polio acute flaccid paralysis (NPAFP) attack rate in the study period ranges from 1.2 in 2014 to 4.4 cases per 100,000 children under 15 years of age in 2018. The stool adequacy varied from 58% in 2020 to 100% in 2011. Four out of eleven counties (Ayod, Nyirol, Pibor and, Pigi, did not report cases for three to five years, while Fangak and Pochalla to one to two years

(Table 2). A total of 244 (71%) cases were reported more than >14 days from the onset of paralysis. Of the reported AFP cases, 312 (90%) were investigated within 48 hours of notification to the county surveillance officer. After investigation and laboratory testing, 328 (95%) of the cases were classified as discarded cases (Table 3). The immunization profile in the study period of the state indicates; 249 (72%) had three or more Oral Polio Vaccine (OPV) doses, 41 (12%) had 1 to 2 doses, 24 (7%) had zero doses (OPV0), and 32 (9%) of missing doses (Table 4). A total of 4 cVDPV2 and 14 compatible cases were also reported from different counties during the study period. Out of the total AFP suspected cases, 25% (85/246) were NP-ENT cases (4).

Table 1: characteristics of acute flaccid paralysis in Jonglei State, South Sudan, 2011-2020

Demographic characteristics	Parameter	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
AFP cases	AFP cases reported	33	41	32	10	23	34	35	45	43	50	346
Gender	Male (N= 175, 51%)	19	18	19	6	11	18	12	23	26	23	175
	Female (N= 171, 49%)	14	23	13	4	12	16	23	22	17	27	171
Vaccination status	Zero doses (N=24, 7%)	0	0	0	1	0	3	0	2	6	12	24
	1-2 dose (N=41, 12%)	4	1	1	1	2	5	3	6	3	15	41
	3+ doses (249, 72%)	29	40	31	7	21	26	24	27	28	16	249
	Missing dose (32, 9%)	0	0	0	1	0	0	8	10	6	7	32
Age	0-5 Years (N= 275, 79%)	29	33	29	7	18	29	28	33	32	37	275
	6-10 Years (N= 43, 12%)	2	5	2	1	2	4	3	6	8	10	43
	11-15 Years (N= 12, 3%)	2	3	0	2	2	0	1	1	1	0	12
	>15 Years (N= 3, 1%)	0	0	1	0	0	0	0	1	0	1	3
	Missing years (N= 13, 4%)	0	0	0	0	1	1	3	4	2	2	13
Clinical history	Fever at the onset of paralysis (N= 325, 94%)	31	35	32	10	23	33	33	41	41	46	325
	Asymmetric paralysis (N= 226, 65%)	21	22	23	7	22	33	25	19	23	31	226
	Paralysis progressed within 3 days (N= 303, 88%)	29	33	25	10	19	32	33	36	39	47	303

Table 2: number of total AFP cases reported by county by year in Jonglei state, South Sudan 2011-2020

County/Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Akobo	4	2	5	1	3	5	2	5	5	4	36
Ayod	4	2	3	0	0	2	0	7	7	11	36
Bor South	6	9	4	3	9	8	11	8	4	1	63
Duk	2	3	1	1	1	6	3	2	5	4	28
Fangak	2	3	4	0	1	2	1	0	1	4	18
Nyirol	2	0	0	0	2	0	0	1	1	6	12
Pibor	1	1	0	0	0	3	5	7	3	8	28
Pigi	1	4	3	0	0	0	0	3	4	4	19
Pochalla	1	2	1	2	1	1	4	5	0	0	17
Twic East	7	9	3	2	2	4	6	4	7	4	48
Uror	3	6	8	1	4	3	3	3	6	4	41
Total	33	41	32	10	23	34	35	45	43	50	346

Table 3: main surveillance indicators for acute flaccid paralysis by County and by year in Jonglei State, South Sudan, 2011-2020											
Parameter	**Main indicators**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Akobo	NPAFP rate	3.7	1.8	4.5	1.1	3.3	5.4	2.1	5.1	4.9	3.8
	Stool adequacy (%)	100	100	80	100	100	60	100	60	40	50
Ayod	NPAFP rate	4.1	2	3	0	0	2.1	0	7.1	6.9	5.7
	Stool adequacy (%)	100	100	100	0	0	100	0	100	71	64
Bor South	NPAFP rate	3.5	5.1	2.3	7.2	21.1	18.2	24.3	17.2	2.4	0.6
	Stool adequacy (%)	100	89	75	100	100	100	91	100	100	100
Duk	NPAFP rate	6.3	9.1	3	1.4	1.4	8.2	4	2.6	8.3	8.1
	Stool adequacy (%)	100	67	100	100	100	100	100	100	80	100
Fangak	NPAFP rate	2.3	3.4	4.5	0	1.3	2.6	1.3	0	1.2	2.3
	Stool adequacy (%)	100	100	100	0	100	100	100	0	100	50
Nyirol	NPAFP rate	2	0	0	0	2.1	0	0	0.9	0	6.1
	Stool adequacy (%)	100	0	0	0	50	0	0	0	0	33
Pibor	NPAFP rate	0.8	0.8	0	0	0	6.8	11	12.8	1.8	4.5
	Stool adequacy (%)	100	100	0	0	0	67	60	86	33	13
Pigi	NPAFP Rate	3	11.7	8.8	0	0	0	0	2.7	4	5.2
	Stool adequacy (%)	100	100	100	0	0	0	0	33	5	7
Pochalla	NPAFP rate	4.1	7.9	3.9	1.4	0.7	0.7	1.9	3.1	0	0
	Stool adequacy (%)	100	100	100	100	100	100	75	100	0	0
Twic East	NPAFP rate	17.5	21.8	7.3	3.7	3.6	7	10.1	6.6	11.1	6.2
	Stool adequacy (%)	100	89	100	50	100	100	100	75	86	100
Uror	NPAFP rate	2.9	5.7	7.5	0.9	3.4	2.5	2.4	2.4	4.6	3
	Stool adequacy (%)	100	100	100	100	100	67	100	100	67	75
Jonglei State	NPAFP rate	3.6	4.3	3.4	1.2	2.6	3.7	3.6	4.4	3.9	3.8
	Stool adequacy (%)	100	93	94	90	96	88	89	84	67	58

Table 4: classification of acute flaccid paralysis in Jonglei State, South Sudan, 2011-2020											
Parameter	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**Total**
AFP cases reported	33	41	32	10	23	34	35	45	43	50	346
% of notification with in <7 days of onset	79	78	72	70	74	88	77	60	70	50	71
% of investigation with in <2 days from notification	100	100	97	100	100	97	80	87	88	72	90
# of inadequate cases	0	2	2	1	1	4	4	7	10	21	52
% of Npent cases isolated	27	29	25	30	35	29	26	16	19	22	25
Number of WPV cases	0	0	0	0	0	0	0	0	0	0	0
Number of cVDPV2 cases	0	0	0	0	0	0	0	0	0	4	4
Number of compatible cases	0	0	0	0	0	0	1	2	4	7	14
Number of discarded cases	33	41	32	10	23	34	34	43	39	39	328

Discussion

The study showed that, although AFP cases were reported from all age groups in the state, the majority (79%) of them were children below the age of five years, this finding is consistent with other states within the country and similar studies conducted in Kenya, Ethiopia, Somalia, and Nigeria [1,3,13,14]. Besides, our findings of gender proportionality of reported AFP cases were consistent with studies conducted in Kenya, Ethiopia, Somalia, and Nigeria with proportions of 55%, 58%, 60%, and 56% respectively [1,3,13,14]. However, no disparity was found while compared with other states within the country. The polio vaccination status of the reported cases was also far from adequate to ensure the establishment of herd immunity in the population. The immunization status of reported cases in Jonglei state is lower than the national figure reported during the same period (66% in 2011 and 50% in 2019). The OPV 3 coverage (percentage of surviving infants who received the 3rd dose of polio-containing vaccine). Similar studies conducted in Kenya from 2016-2018 and in Ethiopia from 2005 to 2015 on reported AFP cases also revealed the immunity profile of AFP cases reported was higher than Jonglei state [1,3]. This finding is also supported by the national immunization coverage survey finding in 2017 that most conflict-affected states including Jonglei have documented a very low level of immunization coverage compared to none-conflict affected states [15,16]. Moreover, perennial flooding had played a critical role in low immunization coverage and led to children´s exposure to cVDPV2 [17]. On the other hand, the proportion of cases with zero doses and those whose immunization status was not known or missing was higher than the national figure for the same period [15]. Most of the counties in the state have reported at least one AFP and NP-AFP case. The overall NP_ AFP rate was two cases per 100,000 in the under 15 years population. Though, in 2014, 45% (5/11) of the counties were silent, which made the state fail to meet the NP-AFP target for the year. The possible reason for the decrease in AFP case reporting and being silent in 2014 was as a result of the conflict in 2013 conflict, which impacted the surveillance system of the state even after the conflict [15]. The trend analysis of the NP-AFP rate was improving from 2015 to 2020, while the stool adequacy rate revealed a decreasing trend with minor fluctuation during the same period [15].

The stool adequacy across all counties chronically low compared to other states within the country. In the same period, even states with a similar situation (unity and upper Nile) achieved the target. One of the factors that may have contributed may be the ongoing inter-clan conflict than any other states on top of the consequence of previous war [18]. The inconsistent and low stool adequacy rate in the state during 2019 and 2020 was due to the occurrence of massive flooding in most of the counties. The situation was aggravated by the untoward consequences of the COVID-19 pandemic in the country. This assumption was also supported by a study conducted globally. There was a 33% decline in AFP case reports and compromised stool adequacy between 2019 and 2020 due to the COVID-19 pandemic [19,20]. Most of the counties in the state have not attained either one of the two major surveillance performance indicators minimum target. Twic East county persistently attended NP-AFP target below two cases per 100,000 children aged < 15 years per year throughout the study period. The proportion of AFP cases notified within seven days of the onset of paralysis was below 80% during the study period, except in 2016 [21,22]. On the other hand, the proportion of AFP cases investigated within 48 hours from the date of notification was above 80% except in 2020. As for the "percentage of cases investigated within 48 hours of notification", the finding is consistent with national figures and most countries in Africa [23]. Close to 15% (52/346) of AFP cases were classified as inadequate and for which, most of these cases were reported late. This signifies that the sensitivity of surveillance network and early detection of AFP cases in the state and counties were suboptimal which doubt the system for undetected circulation virus. The situation is compounded by poor and fragile health systems, insecurity, and natural disaster such as flooding [24]. The none polio AFP NP-AFP) rate for the state was, 1.2 in 2014 to 4.4 per 100,000 children under 15 years in 2018. This finding is comparable with the most recent findings of the neighboring countries such as Kenya and Ethiopia with an average rate of 1.3% and 7.9% respectively [1,3]. However, through the period of analysis, no county attend both indicators consistently, while in other states in most of the counties consistently attained and maintained throughout the study period (polio-free documentation).

Conclusion

The performance of Jonglei´s AFP surveillance system did not meet the WHO recommended minimum target or threshold for both major AFP surveillance indicators (non-polio AFP rate and stool adequacy) during the period studied. Performances of four counties remain a concern and were negatively impacting the performance of the state in attaining the indicators irrespective of external factors and various limitations. Early detection and reporting of cases were sub-optimal. Though the number of AFP cases reported increases slightly year after year, the stool adequacy report showed a decreasing trend even in the counties where community-based surveillance workers (CBS) are deployed. The immunity status of reported cases was also significantly low. To strengthen Jonglei state´s polio-free status, all stakeholders including health facility surveillance focal persons, WHO field supervisors, WHO field assistants, CBS workers need to have an in-depth awareness to improve the sensitivity of AFP surveillance across all counties in the state. In addition, strengthening partners coordination will improve routine immunization coverage and ensure all target children have received the required doses at the right age.

What is known about this topic

- South Sudan and the African continent were certified of circulating wild poliovirus-free status in August 2020;
- Acute flaccid paralysis surveillance is one of the strategies for the polio eradication;
- Surveillance performance indicators are being monitored at the state and counties level to achieve polio eradication.

What this study adds

- The study being the first surveillance paper in the state provided, it had compared relevant information on surveillance performance over years with national, regional, and global standards;
- The study also identified challenges and recommends ways of improving the surveillance performance indicators in the state.

Competing interests

The authors declare no competing interests.

Authors' contributions

JM and TG conceptualize the study and drafted the manuscripts, TG worked on the data analysis and structure. AAT, KKB, and MS coordinated and critically reviewed the manuscript and gave final approval of the version to be published. The authors reviewed the manuscripts, read, and made the final version of the manuscript. All the authors have read and agreed to the final manuscript.

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Research

The sensitivity of acute flaccid paralysis surveillance - the case of South Sudan: retrospective secondary analysis of AFP surveillance data 2014-2019

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Abstract

Introduction: South Sudan has made quite impressive progress in interrupting wild poliovirus and maintaining a polio-free status since the last case was reported in 2009. South Sudan introduced different complementary strategies to enhance acute flaccid paralysis (AFP) surveillance. Hence, the objective of this study is to evaluate the sensitivity of the surveillance system using the WHO recommended surveillance standard and highlight the progress and challenges over the years.

Methods: we conducted a retrospective, descriptive, quantitative study design and used the available secondary AFP surveillance database.

Results: the overall non-polio AFP rate was 6.2/100,000 children under 15 years old in the study period. The stool adequacy was maintained well above the certification level of surveillance. The two main surveillance performance indicators were met at the national level throughout the study period. In contrast, only five out of ten states persistently attained and maintained the two main surveillance performance indicators throughout the study period, while in 2019 all states achieved except for Jonglei state. During the analysis period, no wild poliovirus was isolated except two circulating Vaccine Derived Poliovirus Type 2 (cVDPV2) cases in 2014 and one Immunodeficiency Vaccine Derived Poliovirus Type 2 (iVDPV2) case in 2015. However, on average, three cases were classified as polio compatible with each year of the study.

Conclusion: South Sudan met the two key surveillance performance indicators and had a sensitive AFP surveillance system during the period studied. We recommend intensifying surveillance activities in the former conflict-affected states and counties to maintain polio-free status.

Introduction

Acute Flaccid Paralysis (AFP) surveillance backed by laboratory investigation of stool specimens is one of the four strategies that the Global Polio Eradication Initiative uses to measure the progress towards the polio eradication goal [1-3]. The World Health Organization (WHO) Africa region has made quite impressive progress in interrupting wild poliovirus and maintaining a polio-free status since the last case was reported in Nigeria in August 2016 [4]. Nonetheless, outbreaks of circulating vaccine-derived poliovirus type 2 (cVDPV2) had been reported in several countries of the region following the withdrawal of tOPV [5].

South Sudan has been implementing polio eradication activities while being then in Sudan. Since then, South Sudan has registered significant success resulting in the interruption of transmission of wild poliovirus (WPV) in 2009 and wild poliovirus-free status by the African Regional Certification Commission (ARC) in June 2020. Nevertheless, soon after her independence with a peaceful referendum in 2011, a civil war broke out in 2013 and again in 2016, creating ongoing political instability leading to a protracted communal armed conflict accounting for extreme humanitarian crises. This led to a significant destruction of health facilities and social services, creating more challenging circumstances to provide even the basic health service. Parallel to this, surveillance and immunization activities were hampered due to insecurity, displacement, and geographical inaccessibility that left a blind spot in the sensitivity of the surveillance system in some areas. Nonetheless, the surveillance system has overcome many challenges using innovative strategies such as trained community informants, community leaders, and recruiting field staff from the local population to ensure that insecure and hard-to-reach areas are also covered.

South Sudan's AFP surveillance system is complemented by collecting three stool specimens from close contacts. A study conducted in South Sudan from 2012 to 2016 indicated that 4,687 children contact specimens were collected for 1,637 index AFP cases, and healthy child stool specimens have been collected each month if a county is silent for over 6 months until the county reports a none polio AFP case [6]. Furthermore, a community-based surveillance system was established in the three conflict-affected states following the cVDPV2 outbreak in 2014 to cover the most inaccessible war-affected on top of community informants in all other areas of the country [5]. Moreover, South Sudan´s surveillance system relies on an active surveillance system using Integrated Supportive Supervision (ISS) tool using Open Data Kit (ODK) [7]. The surveillance system also is reviewed by a team of external evaluators every 2-3 years, with the last review done in September 2017 and to further complement the routine AFP surveillance system, environmental surveillance, auto visual AFP case detection, and reporting, reverse cold chain monitoring mechanisms, were introduced [8]. The study aims to evaluate the sensitivity of AFP surveillance in South Sudan using the WHO recommended surveillance standards and highlight the progress and challenges.

Methods

Study area: South Sudan is one of the youngest countries globally, with decades of war and conflict formed in 2011 after a peaceful referendum and ongoing conflict since 2013. The country is bordered to the north by Sudan, to the east by Ethiopia, to the southeast by Kenya, to the South by Uganda, to the southwest by the Democratic Republic of Congo, and the west by the Central African Republic. The population of South Sudan is estimated to be 13.8 million as of December 2019, based on the 2008 census projection. Administratively the country is subdivided into 10 states and 80 counties.

Study design: we conducted a retrospective descriptive quantitative study design using the available secondary data reported to the national AFP surveillance database from 2014-2019.

Study population: all reported AFP cases that fulfilled the case definition and were verified by trained field officers were included in the study.

Acute flaccid paralysis surveillance system: the surveillance system in South Sudan is centered around the health facilities as in many other countries. However, enhanced community-based surveillance was instituted in the three conflict-affected states following the cVDPV2 outbreak in 2014. Furthermore, surveillance networks include government, private, and alternative community healing/treatment facilities that are prioritized into high, medium, and low priority sites. All facilities are mandated to report any suspected cases of AFP and weekly zero reports of AFP. At each administrative level, there are designated Officers who follow the day-to-day operation and conduct active surveillance visits to priority surveillance sites.

Case definition: an AFP case is a child < 15 years of age presenting with sudden onset of flaccid paralysis or muscle weakness due to any cause, or any person of any age with paralytic illness if clinicians suspect poliomyelitis.

Investigation of cases: an initial investigation of suspected AFP cases conducted by health workers and verified by trained field staff, using a standard case investigation form to capture demographic, clinical, and epidemiological information with 60 days follow up investigation of inadequate cases.

Laboratory sample collection and testing: two stool specimens were collected from AFP cases meeting standard case definition with an interval of 24 or 48 hours apart. The collected stool specimens were transported to the national public health laboratory through humanitarian flights with an appropriate reverse cold chain system (2-8°C) and stored at the national level at -20°C until further shipped to Uganda Virus Research Institute (UVRI) for analysis. The condition of the specimens was monitored through tracking mechanisms at each level and recorded in the database. Nearly all specimens are transported to the national level through air flights. Additionally, for each index case, one sample was collected from at least three close contacts irrespective of the geographical areas and stool adequacy.

Final classification: all reported inadequate AFP cases were classified by the National Polio Expert Committee (NPEC) supported by the secretariat. All adequate cases are classified automatically using a virological classification scheme.

Data collection and analysis: the national AFP database collected through the routine surveillance system and stored at the national level from January 2014 to December-2019 was used. Several indicators measured the sensitivity of the surveillance system with a primary focus on two main indicators: i) non-polio AFP rate 2/100000 children < 15 years; and ii) two adequate stool specimens collected at least 24-48 hours´ apart within 14 days from onset of paralysis and reached laboratory in good condition. For this analysis, an electronic MS Access database was exported into the MS Excel and EPI Info for Windows version 7 (Centers for Disease Control and Prevention, Atlanta, United States) to generate a descriptive analysis, frequencies, tables, and graphs. All surveillance performance indicators were evaluated using the WHO-recommended surveillance standard, and the calculation method followed standard methods.

Definitions of terms

Confirmed polio case: a suspected AFP case with WPV isolation from a stool sample.

Non-polio AFP cases: discarded cases are non-polio AFP cases classified by the National Expert Committee after an in-depth review of the cases that exclude all WPV, VDPV, and compatible cases.

Inadequate cases: cases detected over 14 days from the date onset of paralysis and arrival of the specimens, at the laboratory in bad condition.

Main AFP surveillance indicators

Non-polio acute flaccid paralysis rate: an indicator of the sensitivity of the surveillance system. As per the guideline the system should detect at least two AFP cases per 100,000 children below the age of 15 years.

$$Non-polio\ AFP\ rate = \frac{Number\ of\ non-polio\ AFP\ cases < 15\ years}{Total\ number\ of\ children < 15\ years}\ X\ 100{,}000$$

Stool adequacy: defined as two stool specimens collected from an AFP case 24-48 hours apart and within 14 days of onset of symptoms arriving in the lab in good condition. At least 80% of all AFP cases should have adequate stool specimens

$$Stool\ adequancy = \frac{Total\ number\ of\ AFP\ cases\ with\ two\ adequate\ stool\ specimens\ collected\ within\ 14\ days}{Total\ AFP\ cases\ reported}\ X\ 100{,}000$$

Ethical approval and consent: we used the secondary data collected and stored at the national level. Individual verbal consent was received during case investigation and stool sample collection as well as filling of the required information in the AFP case-based form. Administrative clearance for publication of this editorial was provided by the Ministry of Health of South Sudan and WHO (WHO e-Pub IP-00331531-EC) to publish the result. Moreover, the Research Ethics Review Board of Ministry of Health provided clearance for the publication of the manuscript under (MoH/RERB/D.03/2022) clearance number. Moreover, the Research Ethics Review Board of Ministry of Health provided clearance for the publication of the manuscript under (MoH/RERB/D.03/2022) clearance number.

Results

From 2014 to 2019, a total of 2,212 cases of AFP in children under the age of 15 years were reported nationwide by the surveillance system of South Sudan. An average of 369 AFP cases were reported annually, from all 10 states and all counties. Among the 2,212 cases analyzed, 1,115 (50.6%) were male, and the mean age of the children was 3.2 years with a standard deviation of 2.6 years. The largest proportion (76.4%) involved cases are < 5 years old. However, since 2016 a lower percentage of under-5-year-old has been documented. The majority of 1,724 (80%) of the reported cases were detected within 7 days of the onset of paralysis. However, it decreased from 84.6% in 2014 to 78.5 % in 2019, and most (80.9%) cases were investigated within 48 hours of notification with a decline from 2018 onwards (Table 1).

The clinical characteristics of the reported AFP cases indicated that the great majority (98.4%) had a fever at the onset of the paralysis, while in 2028 (91.9%) of these cases, had complete flaccid paralysis within 3 days of the onset of paralysis. Our study also showed that 1,936 (87.5) of the AFP cases reported during the study period had received 4+ doses of OPV, while 3.5% of the children was zero or unknown OPV doses. Over the study period, the proportion of cases that received 4+ doses remained above 82%. The arrival of two adequate stool specimens collected in 24-48 hours at the laboratory in "good condition" was consistently above the established standard of 90% throughout the study period. The Non-Polio Enterovirus (NPENT) isolation rate remained well above the certification level (10%) during the study period, except for 2014. On the other hand, the average days of transporting the specimen from the field to the national level are 14 days and ranged from 12 days in 2014 to 16 days in 2018, and the number of silent counties gradually decreased from 15 in 2014 to 3 in 2019. On the other hand, at least three close contact specimens were collected in an average of 96.4% of the index cases (Table 2)

The analysis results showed that an average of 47 cases were detected per week. However, a significant increase in the number of detected cases was observed from weeks 7 to 14 and again from weeks 34 to 40 of each year. The number of cases started to gradually decrease each year since week 41 as the year's end (Figure 1). The country consistently achieved the NP-AFP rate during the entire study period, well above the standard (2/100,000 children < 15 years). The non-polio AFP rate averaged 6.2/100,000 children < 15 years old, while it increased from 5.9/100,000 < 15 years old in 2014 to 6.3 in 2019. Six states had consistently achieved a non-polio AFP rate well above the target of 2/100,000 children < 15 years of age during the entire study period, while six, eight and 9 states had achieved in 2014, 2015 and 2019 respectively. In the last 3 years of the study period, all states had persistently achieved the target except Central Equatoria state. The analysis of the NP-AFP rate at the county level showed that an average of 78% of counties met the target, an increase from 68% in 2014 to 89% in 2019 (Figure 2).

The stool adequacy was persistently above the target of 80% throughout the study period. Though certification level was maintained, there was a decline in the proportion of stool adequacy in 2017 and 2018. The proportion of two adequate stool specimens at the state level varied, with only five of the ten states persistently attaining the minimum

Table 1: characteristics of AFP cases reported 2014-2019, South Sudan

Description							
	2014	2015	2016	2017	2018	2019	Total(%)
Total AFP cases reported	322	331	323	388	448	400	2212
Age <5 years	260(80.7%)	278(84.0%)	250(77.4%)	293(75.5%)	318(71.0%)	291(72.8%)	1690(76.4%)
Age ≥5 years	62(19.3%)	53(16.0%)	73(22.6%)	95(24.5%	130(29.0%)	109(27.2	522(23.6%)
Total	322(100%)	331(100%)	323(100%	388(1100)	448(100%)	400(100%)	2212(100%)
Female	144(45%)	163(49.2%)	157(48.9%)	200(51.8%)	226(50.7%)	199(49.9%)	1089(49.4%)
Male	176(55%)	168(50.8%)	164(51.1%)	186(48.2%)	221(49.3%)	200(50.1%)	1115(50.6%)
Total	320(100%)	331(100%)	321(100%)	386(100%)	447(100%)	399(100%)	2204(100%)
OPV zero dose	10(3.1%)	12(3.6%)	8(2.5%)	10(2.6%)	13(2.9%)	25(6.3%)	78(3.5%)
OPV 1-3 doses	24(7.6%)	29(8.8%)	20(6.2%)	42(10.8%)	36(8.0%)	47(11.8%)	198(9.0%)
OPV 4+ doses	288(89.4%)	290(87.6%)	295(91.3%)	336(86.6%)	399)89.1%)	328(82.0%)	1936(87.5)
Total	322(100%)	331(100%)	323(100%)	388(100%)	448(100%)	400(100%)	2212(100%)
% of cases with fever at onset	319(99%)	326(98.5%)	319(98.8%)	379(98.4%)	436(97.5%)	393(98.3%)	2172(98.4%)
% of cases paralysis progressed within 3 days	295(91.6%)	306(94.5%)	308(95.4%)	354(91.5%)	402(90.5%)	363(91.0%	2028(91.9%)
% of cases with asymmetrical paralysis	255(79.4%)	293(89.3%)	292(91.3%)	288(80.5%)	300(75%)	254(64.1%)	1682(79.2%)
% of cases investigated within 48 hours of notification	276(85.7%)	289(87.3%)	267(82.7%)	313(80.7%)	348(77.7%)	296(74.0%)	1789(80.9%)
% cases detected within 7 days	264(84.6%)	280(86.2%)	270(85.2%)	293(77.7%)	311(70.4%)	307(78.5%	1725(80.0%)
AFP: acute flaccid paralysis; OPV: oral polio vaccine; %: percentage							

Table 2: surveillance performance indicators final classification of cases, 2014-2019, South Sudan							
Description	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**Average/total**
% of cases with at least three contact specimens collected	297	322	312	363	440	387	297
	(96.40%)	(96.40%)	(96.40%)	(96.40%)	(96.40%)	(96.40%)	(96.40%)
% of stool samples arriving at a national lab in good condition	307	328	318	374(96.4%)	447	399	300
	(96.50%)	(99.10%)	(98.50%)		(00%)	(99.80%)	(82%)
% of stool specimens from which non-polio enterovirus isolated	9.7	11.2	13.2	10.8	7.6	13.8	10.9
% of stool specimens from which sabin like isolates	2.2	4.5	3.2	4.4	3.5	2.5	3.38
% of counties achieved two main indicators	58	71	66	47	57	68	61
% of counties achieved NP_AFP rate	68	77	80	67	84	89	78
% of counties achieved stool adequacy	68	77	71	52	52	73	66
# of silent counties	15	10	4	15	7	3	9
Average days sample arrival from field to national level	12	14	13	14	16	15	14
Timelines of zero AFP reporting	73	86	84	85	83	85	82.7
Inadequate cases reviewed by NPEC			25	50	70	42	0
Inadequate cases discarded			25	45	62	36	0
Final classification							
WPV cases detected	0	0	0	0	0	0	0
cVDPV2 cases detected	2	0	0	0	0	0	2
Discarded cases	318	329	323	440	392	399	2201
Compatible cases	2	1	0	5	8	6	24
NP_AFP: non-polio acute flaccid paralysis; NPEC: National Polio Expert Committee; WPV: wild poliovirus; cVDPV2: circulating vaccine-derived poliovirus type 2							

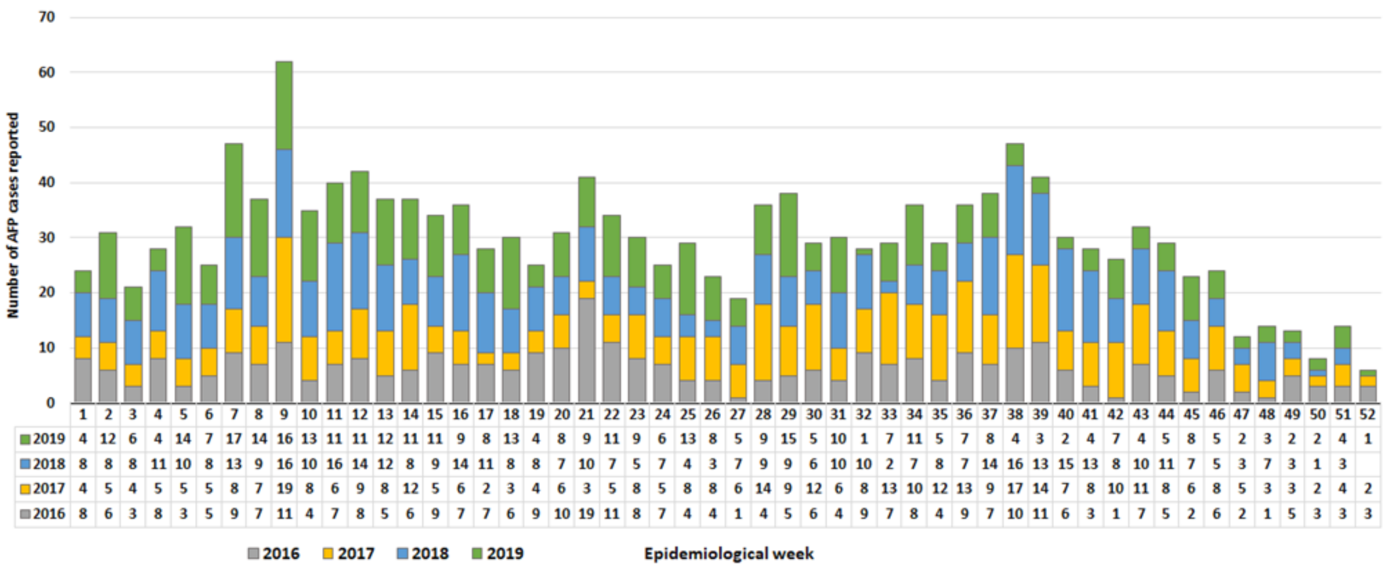
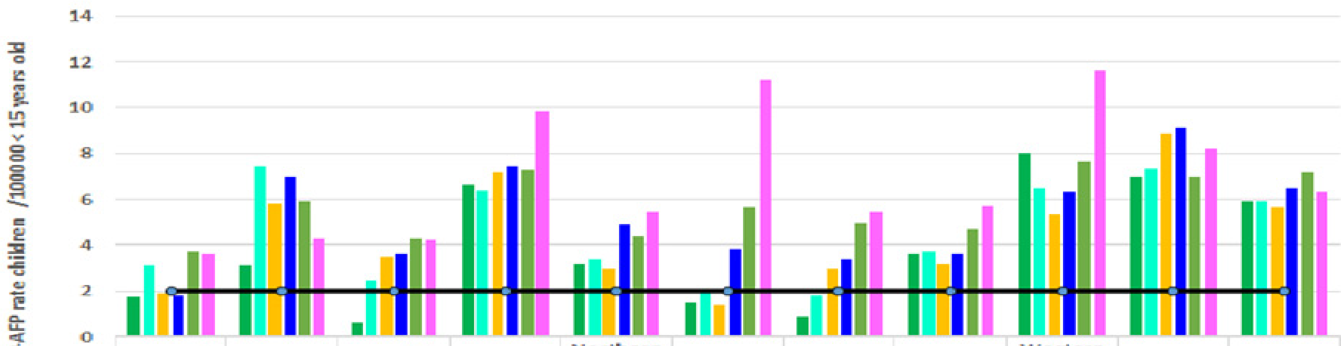


Figure 1: acute flaccid paralysis cases reported by week of onset 2014-2019, South Sudan

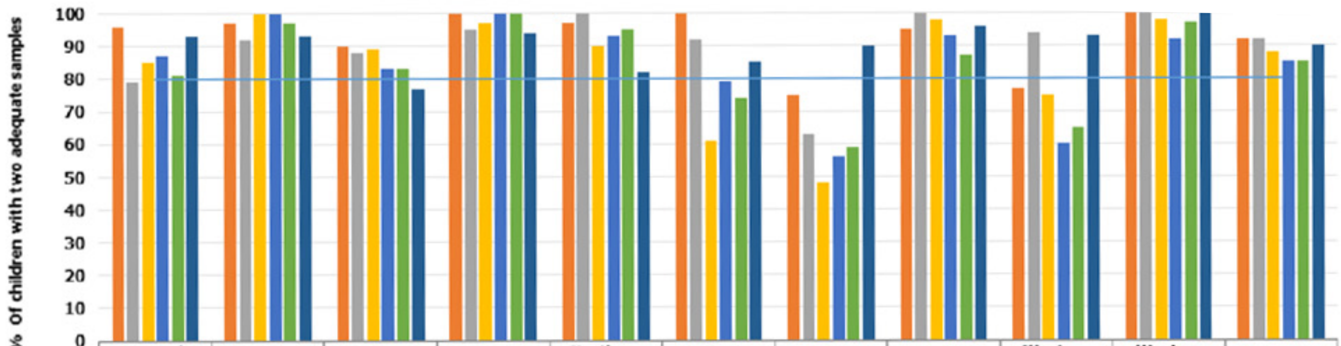


	Central Equatoria hub	Eastern Equatoria	Jonglei hub lakes hub	Lakes	Northern Bahr El Ghazal hub	Unity hub	Upper Nile	Warrap hub	Western Bahr El Ghazal hub	Western Equatoria hub	South Sudan
2014	1.7	3.1	0.6	6.6	3.2	1.5	0.9	3.6	8	7	5.9
2015	3.1	7.5	2.5	6.4	3.4	2.1	1.8	3.7	6.5	7.4	5.9
2016	1.9	5.8	3.5	7.2	3	1.4	3	3.2	5.4	8.9	5.6
2017	1.8	7	3.6	7.5	4.9	3.8	3.4	3.6	6.3	9.1	6.5
2018	3.7	5.9	4.3	7.3	4.4	5.6	5	4.7	7.6	7	7.2
2019	3.6	4.3	4.2	9.8	5.5	11.2	5.5	5.7	11.6	8.2	6.3
Standard	2	2	2	2	2	2	2	2	2	2	2

States

2014 2015 2016 2017 2018 2019 Standard

Figure 2: non-polio acute flaccid paralysis rate by states and year, 2014-2019, South Sudan



	Central Equatoria hub	Eastern Equatoria	Jonglei hub lakes hub	Lakes	Northern Bahr El Ghazal hub	Unity hub	Upper Nile	Warrap hub	Western Bahr El Ghazal hub	Western Equatoria hub	South Sudan
2014	96	97	90	100	97	100	75	95	77	100	92
2015	79	92	88	95	100	92	63	100	94	100	92
2016	85	100	89	97	90	61	48	98	75	98	88
2017	87	100	83	100	93	79	56	93	60	92	85
2018	81	97	83	100	95	74	59	87	65	97	85
2019	93	93	77	94	82	85	90	96	93	100	90
(%) Target	80	80	80	80	80	80	80	80	80	80	80

States

2014 2015 2016 2017 2018 2019 (%) Target

Figure 3: percent of children with two adequate samples by states and year, 2014-2019, South Sudan

required standard over the study period. There was an insistently low performance in Unity, Western and Upper Nile Bahr El Ghazal states for 3, 4 and 5 years respectively. Upper Nile was persistently low performing for 5 years except in 2019. Central Equatoria state fell below the stool adequacy standard in 2015, while Jonglei state fell below the target in 2019. Nevertheless, all states had attained stool adequacy in 2019 except Jonglei state which fell below the standard. The performance at the county level indicates, overall, 61% of the counties attained this indicator with a gradual increase from 68% in 2014 to 73% in 2019 (Figure 3).

The country met the two core indicators in the last six years of the study period. At the state level, however, only five states consistently achieved both indicators over the study period. By 2019, however, all states had managed to meet both core AFP surveillance indicators except for Jonglei state, which fell below the standard for stool adequacy of less than 80%. It is of note that Unity and Western Bahr Ghazal persistently fell below to meet both AFP surveillance core indicators except in 2015 and 2019, while Upper Nile met the two indicators only in 2019 (Figure 4). Further analysis indicated that 61% of the counties met the two main AFP surveillance performance indicators over the study period. A progressive achievement from 58.6% in 2014 to 68% in 2019 (Table 2).

This study indicated that from 2014 to 2019, no WPV case was detected from AFP or environmental samples except that two circulating Vaccine Derived Polio Virus Type 2 (cVDPV2) and one Immunodeficiency Vaccine Derived Polio Virus type 2 (iVDPV2) cases were detected in AFP cases in 2014 and 2015 respectively. Though no WPV case was detected throughout the study period, attenuated Sabin like virus was isolated on average in 3.4% of the stool specimens tested, and over the study period, 22 cases were classified as polio compatible during the study period (Figure 5).

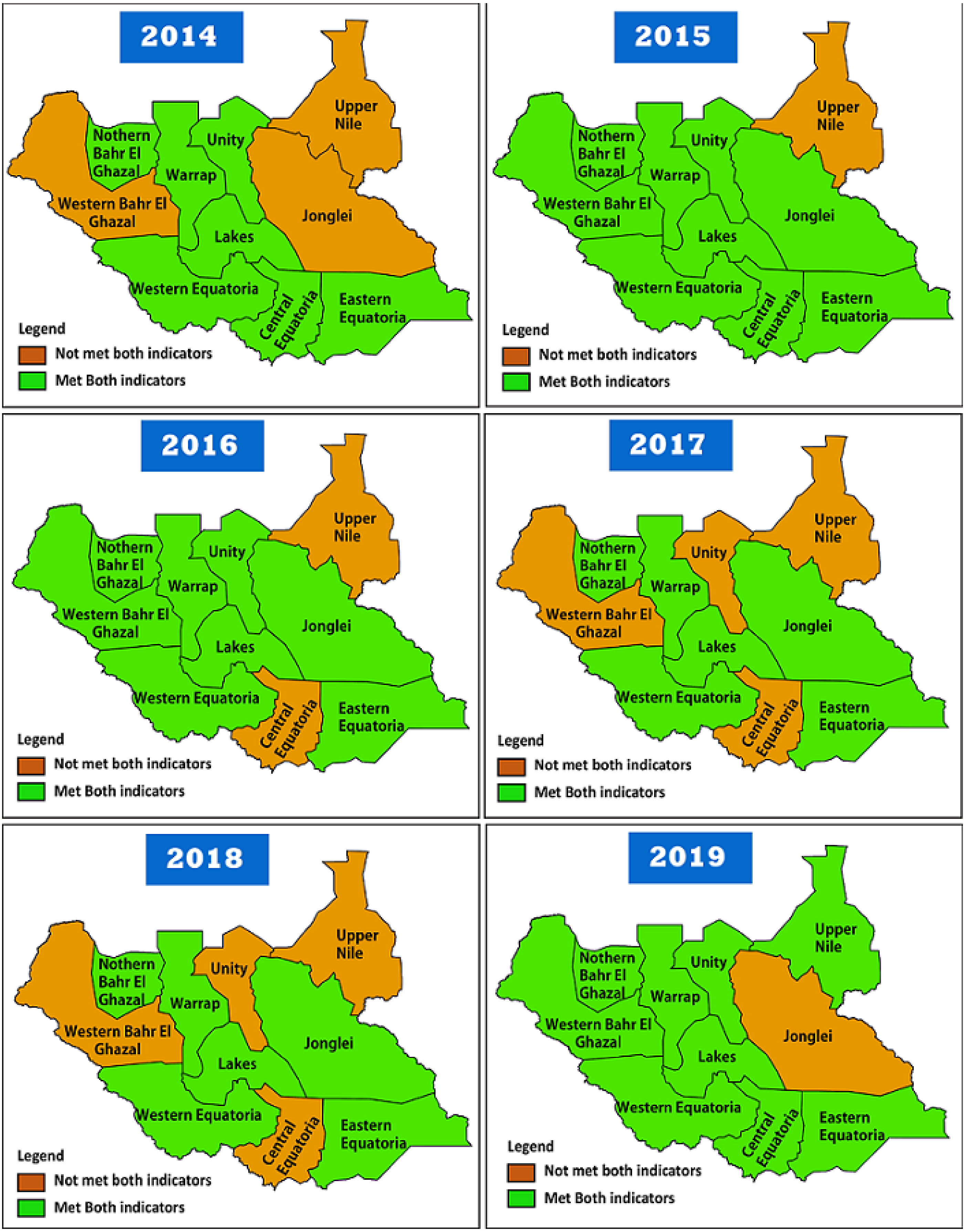


Figure 4: combined two main surveillance indicators (non-polio acute flaccid paralysis rate and stool adequacy), 2014-219, South Sudan

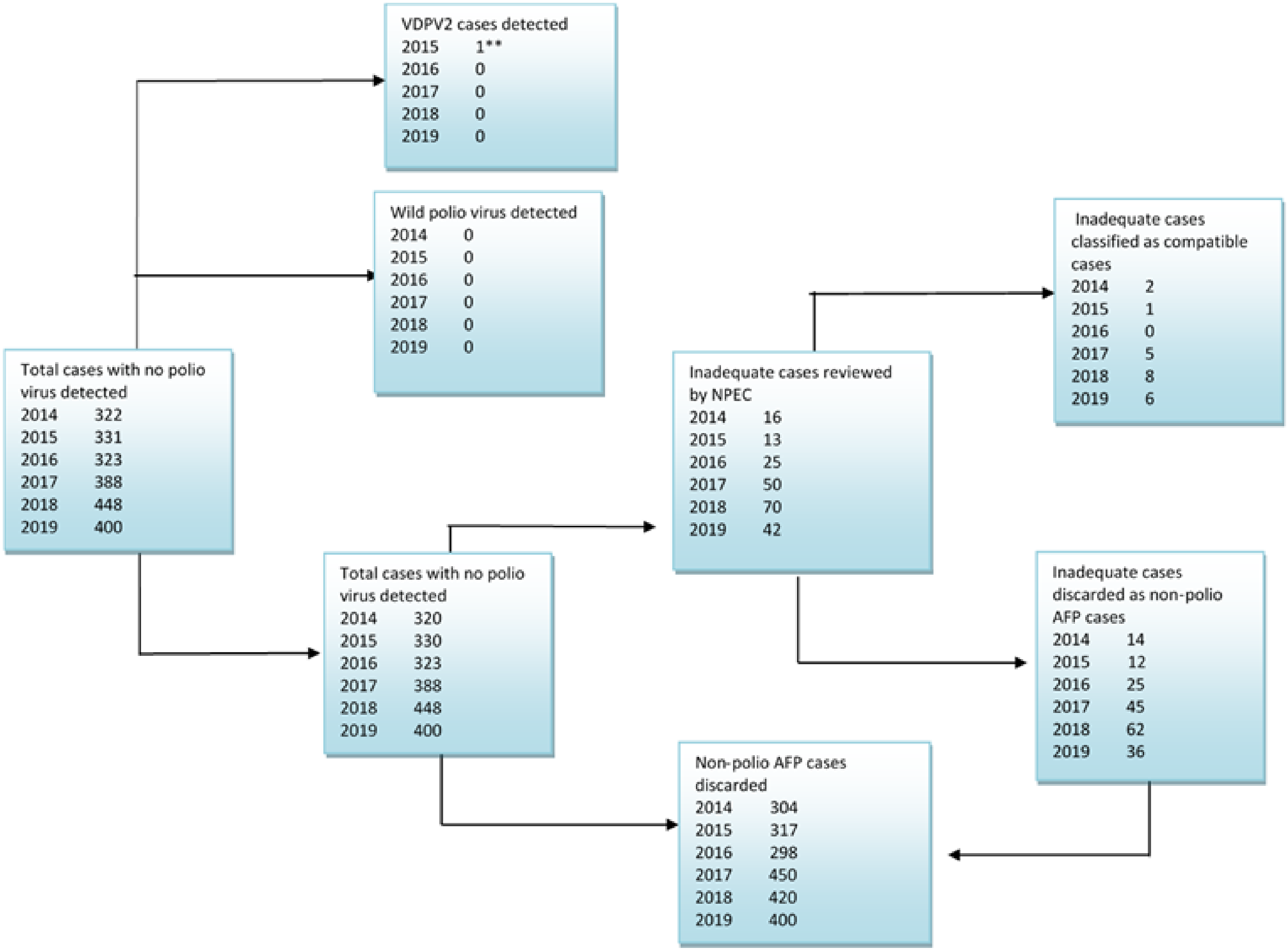


Figure 5: virological classification of acute flaccid paralysis cases 2014-2019, South Sudan

Discussion

The present study reports over a six-year (2014-2019) period in South Sudan to measure the sensitivity of the AFP surveillance system against WHO recommended standard. Our study demonstrated that South Sudan achieved a consistently high NP-AFP rate throughout the study period exceeding well above the WHO recommended minimum surveillance standard [7]. This agrees with previous studies carried out in Egypt and Nigeria [8,9], but higher than the studies conducted in Ghana, Ethiopia, Kenya, Bangladesh and Nigeria [10-14]. The high non-polio AFP rate at the national level can be attributed to the implementation of various strategies to reach insecure and difficult-to-reach areas through the engagement of local personnel. It may also be facilitated by setting up the community-based surveillance system in some states and engaging community informants including introducing AVADAR, Open Data Kit (ODK) and monitoring of staff accountability [15-18]. However, in the three formerly conflict-affected states, despite all these, there was persistent low stool adequacy over the study period, though all states met both indicators in 2019 except Jonglei. The persistently low stool adequacy may be due to the ongoing interclan conflict or a result of the conflict, which has hampered early case detection and notification of cases, including difficulties in transporting specimens due to a dysfunctional public transportation system.

Overall, despite the conflict, uncertainty and humanitarian crises, we found that South Sudan met the two key surveillance performance indicators throughout the study period and was well above the WHO surveillance standard, and also higher than the studies conducted in Kenya and Bangladesh, Zimbabwe and DRC [7, 12, 13, ,18,19,]. Nevertheless, all states did not meet the two main surveillance indicators except in 2019 where all had achieved both indicators except Jonglei. Similarly, the percentage of specimens that arrived in the laboratory in good condition was also well above the certification standard. However, the delays in specimen transport were extremely exceedingly above the maximum WHO-recommended surveillance standard of three days. Interestingly, despite the harsh transportation and delayed arrival of specimens, we found that the isolation rate of non-polio enteroviruses rate is higher than that most of the studies conducted [18-20]. Similarly, early detection of cases within 7 days of onset of paralysis and case investigation within 48 hours of notification is in line with WHO-recommended standard, but lower than the study conducted in Egypt and Ethiopia [7,8,11]. The low rate of AFP stool specimens arriving in the laboratory within three days of the collection is attributed to the logistic problems of shipping specimens. Except for the Central Equatorial State, all collected specimens from all corners of the country are shipped to the national level by humanitarian flights, and these flights are scheduled weekly. Furthermore, the public transportation system connecting the counties to airstrips are in most cases are not functional.

This study revealed the vaccination status of children with more than four doses of OPV was higher than the study done in Uganda and the national routine vaccination coverage [21,22]. However, it was in agreement with other results found in Ethiopia, Kenya and South Africa, but lower than compared to other studies carried out [8,11- 24]. The high vaccination coverage may be related to repeated supplementary immunization campaigns. South Sudan had conducted 3-4 rounds of supplemental immunization activities each year during the study period. However, high population immunity is mainly for poliovirus types 1 and 3 following the global withdrawal of trivalent oral poliovirus in 2016 and low IPV coverage [25,26]. Consequently, population immunity to poliovirus type 2 continues to decline, and hence the risk of cVDPV2 outbreaks remains high. There was no wild poliovirus isolated from AFP or environmental samples during the study period, except for VDPV2 cases in 2014 and 2015.

The high proportion among children aged < 5 years can be attributed to the low standard of living associated with hygiene and sanitation, which leads to infections. Our study also noted that the highest proportion of AFP cases were reported from three states (i.e., Warrap, Lakes, and Western Equatoria). This can be explained by the sensitive AFP surveillance system in these states rather than their population size, as these states contribute only 27% of the country's total population. On the other hand, the high reporting rate in Warrap may have been facilitated by an AVADAR surveillance system in Gogrial West County since June 2018, as most of the cases were reported through the AVADAR system.

We identified some limitations in our study that could adversely affect our study. First, the sub-optimal data with missing and incomplete variables at the begging of the program, however, the data set was cleaned, and some missing variables were captured from the field and case-based forms stored at the national level before data analysis. On the other hand, those grossly incomplete datasets were excluded from the analysis. Though there are limitations, our study highlighted the major strengths and weaknesses of the surveillance system that can assist decision-makers

Conclusion

We concluded that the AFP surveillance system in South Sudan was effective in meeting the WHO recommended surveillance standard for the last six years, and it is highly sensitive enough to detect minimal circulation due to importation or re-emergence of poliovirus in the country. However, sub-optimal surveillance does exist in the former conflict-affected states and Western Bahr Ghazal state, mainly with low stool adequacy, which needs to be improved. To maintain polio-free status, we recommend maintaining and strengthening ongoing surveillance activities, with a particular emphasis on conflict-affected states and counties. We also suggest re-designing strategies to fast-track stool transportation mechanisms to cut down the delay to meet the WHO standard by looking at other options for transporting specimens and monitoring using Log Tag in counties with the critical concern of delayed shipping of stool specimens. Taking into consideration the contribution of United Nation Humanitarian air service flight in specimen shipment, we recommend a frequent detailed discussion with management of humanitarian flight to reduce delays of shipment. Furthermore, we recommend ensuring good quality of data, harmonization of data with laboratory and institute community-based surveillance to early detect cases, enhanced monitoring, and analysis of surveillance data completeness.

What is known about this topic

- A sensitive and effective surveillance system is critical to eradicating poliomyelitis;
- Active surveillance for AFP has been designed for AFP surveillance to rule out undetected circulation;
- It is also critical to achieving main surveillance indicators as well as to sensitize and build the capacity of health workers at the peripheral level.

What this study adds

- Security challenges played a significant role in achieving surveillance indicators in remote and inaccessible areas. However, in this case, using community leaders and informants greatly improved the sensitivity of the surveillance system;
- For the first time, the AFP surveillance data in South Sudan has been systematically analyzed, providing researchers with an opportunity to undertake further detailed research on various factors that affect the sensitivity of the surveillance system in high-risk countries;
- There is a significant improvement in the AFP surveillance indicators of the country, and the surveillance is sensitive enough to pick up any poliovirus circulating. However, there is a need to continue the current momentum to maintain surveillance sensitivity.

Competing interests

The authors declare no competing interests.

Authors' contributions

AAT conceived the study, designed the study, analysed the data, and drafted the manuscript, including a review of the literature; SM contributed to the design of the study and reviewed the article; OOO critically revised the manuscript for important intellectual content and made contributions to the study design and the entire content of the first draft; PDM reviewed the draft and made a substantial contribution; MP reviewed the final draft, commented on the content and approved publication. All other authors have read and agreed to the final manuscript.

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Research

Integrated disease surveillance and response in humanitarian context: South Sudan experience

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Abstract

Introduction: decades of instability continue to impact the implementation of the Integrated Disease Surveillance and Response (IDSR) strategy. The study reviewed the progress and outcomes of rolling out IDSR in South Sudan.

Methods: this descriptive cross-sectional study used epidemiological data for 2019, 2020, and other program data to assess indicators for the five surveillance components including surveillance priorities, core and support functions, and surveillance system structure and quality.

Results: South Sudan expanded the priority disease scope from 26 to 59 to align with national and regional epidemiological trends and the International Health Regulations (IHR) 2005. Completing the countrywide rollout of electronic Early Warning Alert and Response (EWARS) reporting has improved both the timeliness and completeness of weekly reporting to 78% and 90%, respectively, by week 39 of 2020 in comparison to a baseline of 54% on both timeliness and completeness of reporting in 2019. The National Public Health Laboratory confirmatory testing capacities have been expanded to include cholera, measles, HIV, tuberculosis (TB), influenza, Ebola, yellow fever, and Severe Acute Respiratory Syndrome 2 (SARS-COV-2). Rapid response teams have been established to respond to epidemics and pandemics.

Conclusion: since 2006, South Sudan has registered progress towards using indicator and event-based surveillance and continues to strengthen IHR (2005) capacities. Following the adoption of third edition IDSR guidelines, the current emphasis entails maintaining earlier gains and strengthening community and event-based surveillance, formalizing cross-sectoral one-health engagement, optimal EWARS and District Health Information Systems (DHIS2) use, and strengthening cross-border surveillance. It is also critical that optimal government, and donors' resources are dedicated to supporting health system strengthening and disease surveillance.

Introduction

Public health security is essential to minimizing the impact of acute public health events and is critical for countries' social and economic stability and transformation [1]. Health security is even more critical in fragile humanitarian settings given the constrained health and social services and the vulnerabilities to disease outbreaks and other public health emergencies, hence the high likelihood of excess morbidity and mortality. The International Health Regulations (IHR, 2005) mandate countries to establish and maintain effective surveillance and response systems to preserve national and international public health security [2]. The Integrated Disease Surveillance and Response (IDSR) is a strategy for strengthening national public health surveillance and response systems at all levels and provides a framework for attaining the IHR (2005) core capacity requirements in the African region [3,4]. Member states in the WHO African region adopted the strategy in 1998.

Numerous years of civil strife in South Sudan and inadequate public health and healthcare investments have contributed to the increased risk of outbreaks and insufficient capacities to detect and respond to public health threats. Within this context, in 1998, South Sudan experienced a relapsing fever outbreak that is estimated to have resulted in more than 400,000 cases, including 2,000 deaths (CFR 5 0.5%) [5]. The Early Warning Alert and Response Network (EWARN) was established in 1999 within Operation Lifeline Sudan (OLS) initiative to ensure timely detection and prompt response to similar public health threats. The IDSR strategy was eventually launched in 2006 to replace and expand EWARN [5]. However, systematic IDSR implementation started in 2009 after securing grants from USAID and ECHO through the World Health Organization (WHO) [6].

Since the adoption of IDSR by the WHO Africa (WHO-AFRO) Region in 1998, the strategy has been implemented successfully in stable countries. The strategy has been used to improve capacities to respond to cholera, meningitis, Ebola Virus Disease (EVD) and other outbreaks or public health events. In this present paper, we share the experiences and impact of using IDSR to strengthen national surveillance and response systems in a country experiencing a protracted grade 3 humanitarian crisis that has persisted since 2014 with a scale that warrants major support from WHO and other United Nations Agencies [7]. These experiences will inform the updating of current guidance on implementing the IDSR strategy in fragile settings and thus reduce the risk of excess morbidity and mortality.

Annex 1: integrated disease surveillance and response indicator matrix

No	Component	Element	Indicator	Indicator definition	Target	Data source/ method
1.1	PH priorities targeted for surveillance	Prioritizing PH events for surveillance	Objectives for disease surveillance	Exitance of objectives for national disease surveillance	Every 5-10 years	Surveillance guidelines, plan
1.2	PH priorities targeted for surveillance	Prioritizing PH events for surveillance	Disease prioritization	Evidence of prioritization of diseases for surveillance	Every 5-10 years	Surveillance guidelines, plan
1.3	PH priorities targeted for surveillance	Prioritizing PH events for surveillance	Updated priority diseases list	Number of years since the last update of the priority disease list	Every 5-10 years	Surveillance guidelines, plan
2.1	Structure	Surveillance legislation (laws and regulations)	Legislative support for the implementation of surveillance and response	Existence of legislation for surveillance and response	Existence of PH legislation	Document review (JEE report)
2.2	Structure	Surveillance legislation (laws and regulations)	Decree or orders for surveillance and response	Existence of a decree or order for surveillance and response	Existence of decree or order for PHSR	Document review (outbreak response)
2.3	Structure	Compliance with IHR (2005)	Presence of national IHR focal point	Designated IHR focal point	existence of national IHR FP	Document review (JEE report)
2.4	Structure	Compliance with IHR (2005)	Functioning IHR communication facilities	Evidence of functional email/telephone at IHR focal point for international notification and reporting	existence of communication facilities	Document review (JEE report)
2.5	Structure	Compliance with IHR (2005)	Timely notification to WHO of outbreaks of international importance	Proportion of outbreaks of international concern that were notified to WHO within 24 hours of detection	80-100%	Document review (JEE report)

Methods

This was an observational, descriptive cross-sectional study that used the quantitative program and aggregate epidemiological data for all the epidemiological weeks in 2019 and 2020 to document the progress of implementing IDSR and building national surveillance and response capacities in South Sudan. Additionally, other IDSR program data from 2006, were compared with program benchmarks to document the implementation progress. The study used Ministry of Health (MoH) IDSR and Early Warning Alert and Response Network (EWARN) data collected routinely at the health facility, county, and state levels or from periodic program monitoring reports during the study period. Program reports, including monitoring, training, support supervision, and periodic assessment reports, were reviewed to obtain the information on the program performance indicators (Annex 1). The surveillance system components assessed include the availability of a list of priority diseases, conditions, and events for surveillance; the structure of the surveillance system; the core and support functions; and the quality of the surveillance system (Annex 1) [8]. We identified sub-components and relevant indicators for demonstrating progress on the capacity benchmarks established under the IDSR strategy (Annex 1) [8]. We used existing routine MoH aggregate data and coded case-based data with no personal identifiers. We collated the data on surveillance performance indicators into the study data abstraction tool.

The periodic indicator measures were compared to the program targets during the study period to document quantitative and qualitative changes that demonstrate program performance concerning set indicator-specific targets. Quantitative changes in program performance indicators entailed absolute measurements, proportions, or rates. These descriptive analyses were undertaken in Microsoft Excel. We used aggregate data from routine Ministry of Health epidemiological bulletins and program reports with no personal identifiers, and therefore, an ethical review was not warranted for this present study.

Ethics approval and consent to participate: administrative clearance for publication of this paper was provided by the Ministry of Health of South Sudan and WHO (WHO e-Pub no: ePub-IP-00331294-EC).

Results

We present the performance on indicators aligned to the five surveillance system components starting with the surveillance priorities, then the core and support functions, and surveillance system structure and quality.

Surveillance priorities: South Sudan adopted the IDSR strategy in 2006, but systematic implementation aimed at establishing national surveillance structures aligned to the strategy started in 2009. These initiatives were further buttressed when South Sudan became a WHO Member State on 27 September 2012 and after the country committed to the IHR (2005) on April 16, 2013.

Objectives for disease surveillance: the national surveillance goals are aligned to the IHR (2005) and the IDSR strategy for the African region 2020-2030. Thus, the South Sudan Ministry of Health adapted the third edition IDSR guidelines and training materials during a 5-day WHO-facilitated workshop from October 21, 2019. The Government eventually adopted these guidelines on November 13, 2019 thus paving the way for their dissemination and use by counties, health facilities and communities. Based on these guidelines, the main objective of the national surveillance system is to improve the country´s capacities to detect, report, confirm, and effectively respond to priority diseases, conditions, and events. The updated guidelines are explicit on one-health surveillance for zoonotic diseases, the use of eHealth to enhance surveillance, cross-border surveillance strengthening, and surveillance in humanitarian contexts.

Prioritization of diseases for surveillance: as part of the revised 2019 national IDSR guidelines, the priority list was updated from the 26 diseases, conditions, and events prioritized in the 2012 guidelines to 59 diseases, conditions, and 19 events for indicator and event based surveillance (Annex 2 and Annex 3). The broad categories include diseases, conditions, or epidemic-prone events, diseases targeted for eradication or elimination; other major diseases of public health importance; and diseases or events of international concern (Annex 2 and Annex 3). The top cause of morbidity in South Sudan in 2019 was

Annex 2 **:** integrated disease surveillance and response list of priority diseases, conditions, and events

Number	Category	Disease, condition, or event
1	Epidemic prone diseases and/or reportable on a weekly basis	Malaria (suspected and confirmed)
2		Cholera 1
3		Acute watery diarrhoea
4		Bacterial meningitis
5		Diarrhoea with blood (Shigella)
6		Viral haemorrhagic fevers*1
7		Dengue
8		Typhoid fever
9		Yellow fever 1
10		Measles
11		Chickenpox
12		Diphtheria
13		Pertussis (whooping cough)
14		Influenza-like illness (ILI)
15		Severe Acute Respiratory Infection (SARI)
16		Plague 1
17		Relapsing fever
18		Nodding syndrome
19		Brucellosis
20		Zika
21		Coronavirus disease 2019 (COVID-19)
22	Epidemic prone diseases and/or reportable on a weekly basis	Acute Jaundice Syndrome
23		Animal bites (suspect rabies)
24		Snake bites
25		Visceral leishmaniasis (Kala azar)
26		Anthrax
27		Chikungunya
28		Maternal deaths
29		Perinatal deaths
30		Adverse Events Following Immunization
31		Presumptive Multi Drug Resistant TB (MDR-
32		Gunshot/shell injury
33		Other injury
34		Skin disease (scabies, etc.)
35		Malnutrition
36	Diseases targeted for eradication or elimination	Dracunculiasis (Guinea worm)
37		Leprosy
38		Neonatal tetanus
39		Poliomyelitis 1 (AFP)
40		Onchocerciasis
41		Lymphatic filariasis
42	Other major diseases of public health importance	Diarrhoea in children <5
43		Pneumonia <5
44		HIV new cases
45		Tuberculosis
46		Sexually Transmitted Infections (STIs)
47		Human African Trypanosomiasis (HAT)
48		Buruli ulcer
49		Schistosomiasis
50		Soil Transmitted Helminths (STH)
51		Trachoma
52		Acute viral hepatitis
53		Hypertension
54		Diabetes mellitus
55		Epilepsy
56	Diseases or events of international concern	Human influenza due to a new subtype
57		Severe Acute Respiratory Syndrome (SARS)
58		Smallpox
59		Any other public health event of international or national concern (infectious, zoonotic, food borne, chemical, radio nuclear, or due to

Immediate notification and weekly reporting
- Epidemic prone diseases
- Targeted for elimination or eradication
- Events of unknown cause or potential PHEICs
- National/international requirement

Monthly reporting
- All the other diseases, events of public health importance are reported on monthly

Annex 3 **:** integrated disease surveillance and response list of events under event-based surveillance.

Number	Category of event	Disease, condition, or event (for immediate reporting)
1	Human	Clustered human cases of disease or syndromes
2		Unusual disease patterns
3		Unexpected cluster deaths at community level
4		Events that constitute potential public health risk to humans
5		Unusual drug consumption patterns
6		Student absenteeism because of illness
7		Death due to suspect epidemic prone disease
8		Death of a mother or new-born
9		Any other public health event of national or international concern: (Infectious, zoonotic, foodborne, chemical, or radiological, unknown
10		Stock out on 50% of tracer medicines at HF
11	Animal and environmental	Bleeding in livestock or wildlife
12		Unusual animal deaths
13		Unusual deaths of birds - domestic or wild
14		Unusual deaths of fish
15		Abortion in small animals (goats, sheep etc.)
16		**Emergencies: (**floods, population displacement, fires, landslides, earthquakes, extensive crop failure or crop diseases/pests, mass casualty events)
17		Toxic dump on land or water body
18		Hand pump breakdown
19		Attacks on health worker, health facilities or other health resources

malaria that accounted for 75.9% of outpatient consultations and hence is top on the priority list (Table 1). The additional diseases prioritized include vaccine-preventable diseases like pertussis, chickenpox, and suspect rabies, as cases have been on the rise in under-vaccinated populations after emerging as major causes of morbidity and mortality in recent years (Table 2).

Structure of Integrated Disease Surveillance and Response

Legislation to facilitate surveillance: the IDSR strategy has been incorporated into the National Health Policy (2016-2026) and the National Health Sector Development Plan (2017-2022) to facilitate the implementation of IDSR in South Sudan. However, the public health bill and the animal health bill have not been enacted as Acts of Parliament as of writing this report.

Legislation to facilitate outbreaks and emergency response: the overall mandate for regulation and provision of healthcare and health emergency response is constitutionally vested in the national and state governments. Consequently, the Minister of Health has sanctioned the formation of national and state-level outbreak task force committees to control outbreaks of cholera, measles, hepatitis E, and other public health events in recent years. In the same way, presidential orders were issued to establish the National COVID-19 task force to provide the overall policy, strategic, and oversight guidance and coordination of the national COVID-19 response.

Compliance with International Health Regulations (2005)

Designation of National International Health Regulations Focal Point: in line with the IHR (2005) requirement, the office of the Director General International Health and Coordination in the National Ministry of Health is the designated IHR (2005) National Focal Point (NFP) for coordinating IHR (2005) core functions implementation in collaboration with other sectoral focal points.

Table 1: top causes of morbidity in South Sudan in 2019

Disease or syndrome	Morbidity in week 52, 201		Cumulative morbidity for all weeks in 2019	
	Number of cases	Proportional morbidity [%]	Number of cases	Proportional morbidity [%]
Malaria	28,373	60.8%	2,728,314	75.9%
ARI	8,610	18.5%	335,190	9.3%
AWD	5,753	12.3%	440,650	12.3%
Bloody diarrhoea	879	1.9%	73,688	2.1%
AJS	4	0.0%	681	0.0%
Measles	160	0.3%	3,208	0.1%
Other	2,866	6.1%	12,403	0.3%
Total cases	46,645	100%	3,594,134	100%

ARI - acute respiratory illness; AWD - acute watery diarrhoea; AJS - acute jaundice syndrome

Table 2: selected diseases that emerged from 2017 to 2019

#	Disease	Cases	Deaths	CFR	Attack rate per 10,000	Year	Location
1	Pertussis (probable)	10	0		0.91	2019	Leer
2	Chickenpox	38	0		2.49	2019	Awerial
3	Chickenpox	2701	0		91.13	2017	Wau
4	Suspect rabies	38	1	2.6%	6.18	2018, 2019	Nzara
5	Suspect rabies	679	0		84.85	2019	Agok (Abyei)

CFR - case fatality ratio

Functioning International Health Regulations communication facilities: while the National IHR Focal Point has been designated, staffing and communication logistics remain inadequate for the office to meet functional and communication objectives. Official communication email and telephone facilities have not been designated for efficient communication with the other sectors and the WHO IHR focal point.

International notification of outbreaks to World Health Organization: in compliance with the IHR (2005), an outbreak of yellow fever in Sakure, Nzara County and measles outbreaks in 20 counties were notified to WHO as potential Public Health Emergencies of International Concern (PHEIC) in 2019.

Surveillance strategy and coordination

National Integrated Disease Surveillance and Response and Early Warning Alert and Response Network Coordination: the Emergency Preparedness and Response (EP&R) department under the Directorate of Preventive Health Services in the national MoH is the designated IDSR coordination unit at the national level. It is supported by state-level surveillance focal points in the respective state MoH (Figure 1). Within the states, county surveillance officers in respective county health departments (CHDs) support IDSR functions at the county, health facility and community level (Figure 1). All health facilities, including the partner supported EWARN clinics, report to and are supported by the respective county and state-level surveillance officers. The national EP&R department provides oversight, policy, quality assurance, and strategic guidance to implement IDSR in the country.

The emergency preparedness and response committee and its roles in integrated disease surveillance and response coordination: the EP&R department is also the secretariat of the national EP&R committee. The EP&R committee comprises Public Health Officers, Laboratory focal point, and partners from all the programs mandated to manage the priority diseases under surveillance, the National Public Health Laboratory (NPHL) and the health promotion department. The committee also provides strategic and operational guidance on strengthening IDSR core and support functions at all levels. The EP&R committee convenes weekly to review and support preparedness for anticipated outbreaks and public health emergencies; coordinates initial investigations and responses to

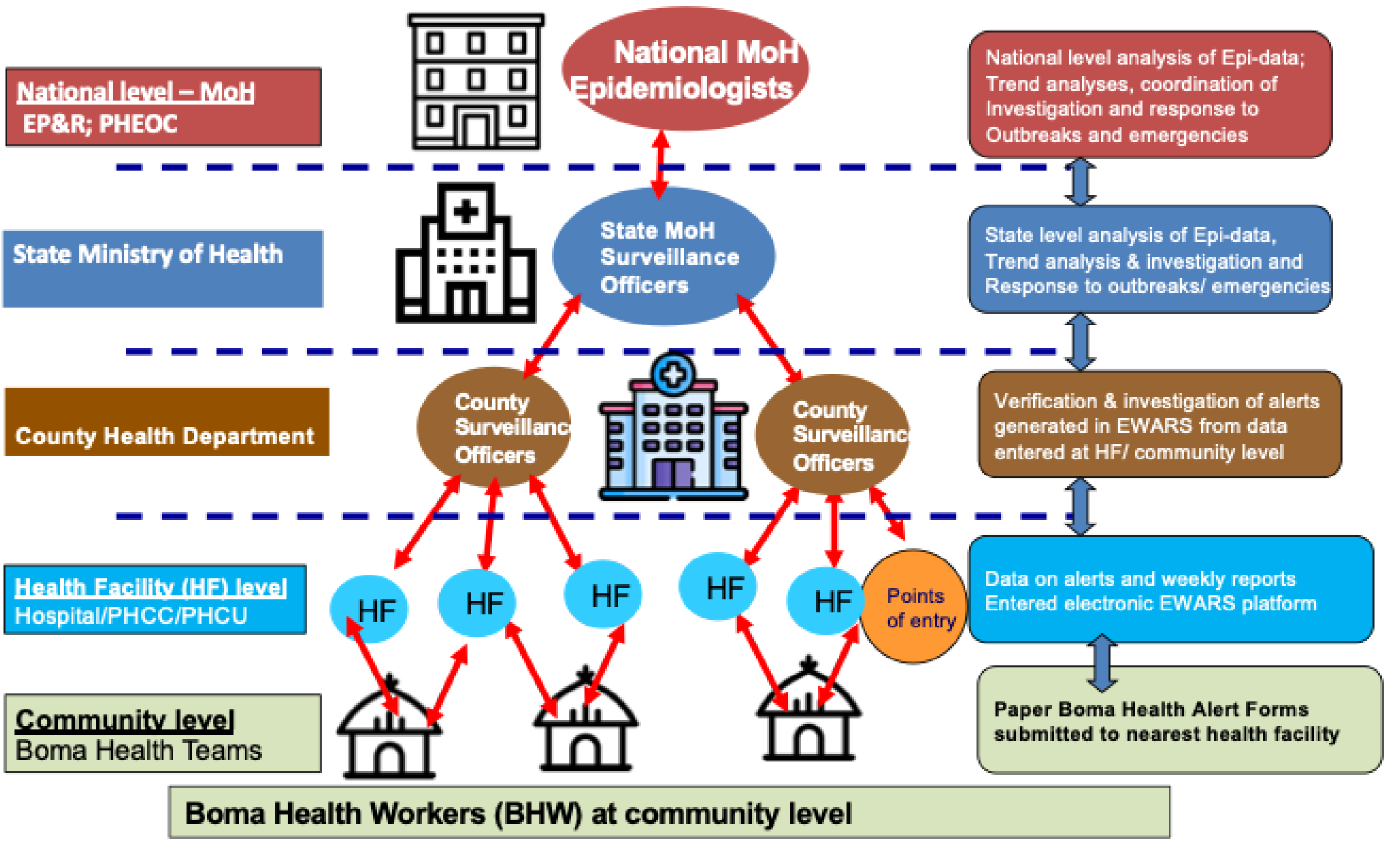

Figure 1: integrated disease surveillance and response functions by health system level in South Sudan

Table 3: laboratory sample testing for selected priority diseases in 2019

No.	Disease (test)	Number of samples			Comments
		Tested	Positive	Negative	
1	Vibrio cholerae (culture)	134	0	134	
2	Measles (ELISA)	671	313	358	Of the 358 samples that tested negative for measles, 155 tested positive for Rubella IgM
3	Influenza (PCR)	309	31	228	
4	Ebola (PCR)	30	0	37	
5	Yellow fever	41	3		
6	Hepatitis E virus (PCR)	71	57	14	

ELISA - enzyme-linked immunosorbent Assay; PCR - polymerase chain reaction

new and ongoing suspect or confirmed outbreaks and other public health emergencies. In 2019, there were 14 (27%) documented weekly EP&R meetings with minutes on the record.

Evidence of sharing resources: to optimize IDSR functional capacities at all levels, integrated use of resources occurs through detection and reporting of acute flaccid paralysis (AFP), Guinea worm, other vaccine-preventable diseases (VPDs) to the respective vertical programs for case-based investigations. The integrated use of IDSR rapid response teams (RRTs) and surveillance focal points to investigate and respond to AFP, Guinea worm disease (GWD), and other VPDs. The use of IDSR/EWARS reporting resources to support reporting needs under the DHIS2 has also been initiated. Further, influenza sentinel surveillance resources under IDSR have been used to support Ebola virus disease, yellow fever, and COVID-19 investigations and laboratory testing.

Networking and partnerships

Intersectoral collaboration, networking, and partnership: effective control of outbreaks like cholera, Rift Valley Fever, Ebola virus disease, and COVID-19 requires the competencies of a designated intersectoral committee for systematic risk assessment, contingency planning, and effective response. However, South Sudan lacks a formalized multisectoral platform to take on this role. Moreover, recent intersectoral engagements are timebound and restricted to the active phase of outbreaks and emergencies. During the cholera outbreaks of 2014-2017, the Ministry of health and partners worked alongside the Ministry of water and irrigation and Juba City Council to implement water quality surveillance and improve access to safe water sources. In the same way, the Ministry of Livestock and Fisheries (MLF) has worked with the Ministry of Health and partners under the task force constituted to respond to the Rift Valley Fever (RVF) outbreak of 2017.

Existence of functional laboratory networks: South Sudan has one National Public Health Laboratory (NPHL) that was founded in 1974 but was not inaugurated until 2014 and has capacities to test for cholera, measles, human immunodeficiency virus (HIV), tuberculosis (TB), influenza, Ebola, Marburg, yellow fever, severe acute respiratory syndrome coronavirus 2 (SARS-COV-2), and routine water quality testing (Table 3). The laboratory reagents and supplies required to support the NPHL to conduct the tests availed through partners like WHO with

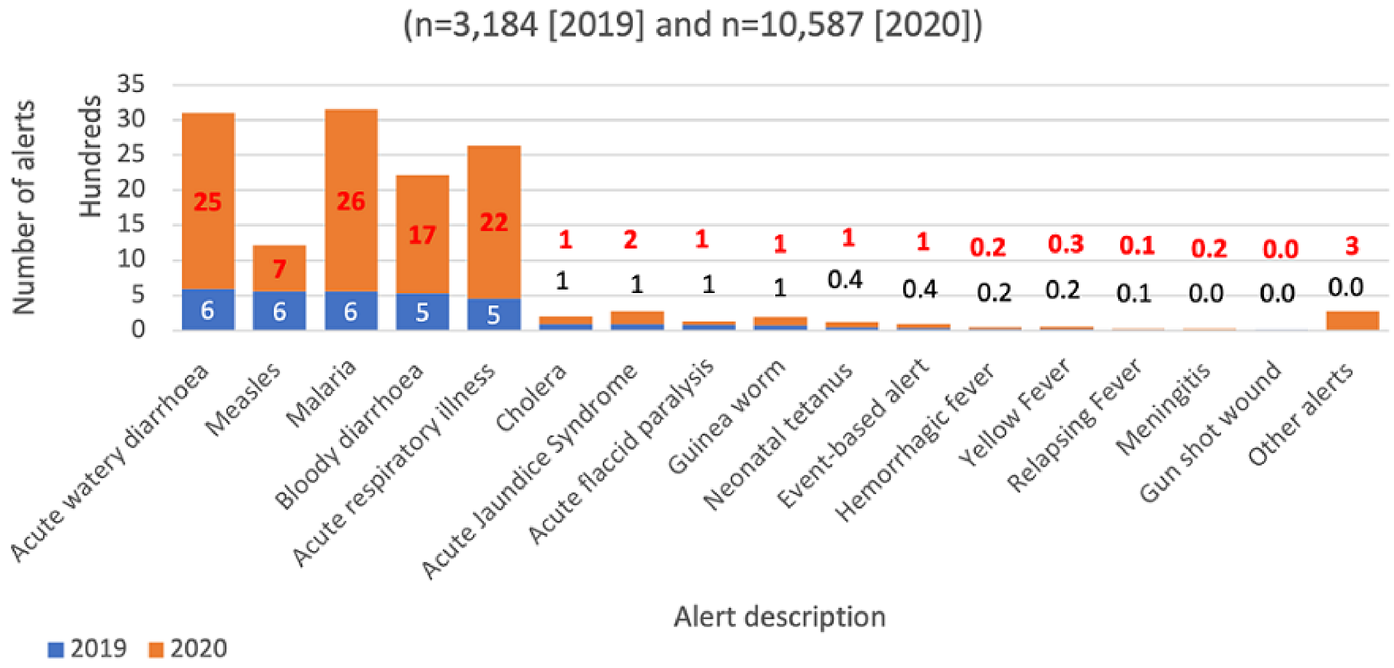

Figure 2: number of alerts by disease, South Sudan, 2019

Table 3: laboratory sample testing for selected priority diseases in 2019

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5	Yellow fever	41	3		
6	Hepatitis E virus (PCR)	71	57	14	

ELISA - enzyme-linked immunosorbent Assay; PCR - polymerase chain reaction

funding support from USAID, ECHO, and Country-Based Pooled Funds (CBPF); UNDP with funding support from the Global Fund; and CDC with funding from The President´s Emergency Plan For AIDS Relief (PEPFAR). There are currently only two molecular laboratories at the sub-national level (Nimule and Wau). Hence, most of the samples are shipped using United Nations (UN) and Non-Governmental Organization (NGO) humanitarian flights and, to a lesser extent, by commercial carries to Juba, where the NPHL is situated. Public health testing is either done at NPHL or designated WHO international collaborating laboratories. Since measles was the most frequent outbreak reported in 2019 from 20 counties, we used it as a proxy for assessing the capacity of NPHL to process samples efficiently. The median turnaround time for measles samples from the field to the NPHL in 2019 varied from one day to 123 days. While the median turnaround time for testing measles samples in 2019 was 5 days and ranged from 1 day to 129 days. The capacities for antimicrobial resistance, monitoring of food safety, and routine external quality assurance are critical and need to be established as required under IDSR and IHR (2005).

Cross-border collaboration: the EAC cross-border surveillance framework was promulgated in 2011, with South Sudan joining in 2017 and participating in annual cross-border meetings since 2018. Cross-border surveillance zones and committees were formed to foster information sharing, regular meetings, joint training, simulations, investigations, and response. During the cross-border surveillance meeting held from 24 to 26 April 2018 in Nimule, South Sudan, the ninth zonal cross-border committee was formed as a tripartite zone covering Kenya, South Sudan, and Kenya. This cross border committee includes surveillance, laboratory, public health, and veterinary officers from the 19 border districts or counties (one district in Kenya; eight counties in South Sudan; and 11 districts in Uganda). The committee members share disease surveillance information regularly, and a social media platform was created to complement the other official communication channels. The tripartite cross-border surveillance committee meets annually and has conducted one joint cross-border outbreak response simulation exercise on the Ebola virus in 2019. The committee has also conducted two cross-border outbreak investigations on Rift Valley Fever and yellow fever in 2019 and 2020, respectively. The later investigation resulted in the confirmation of a yellow fever outbreak in Kajo-keji county in March 2020. Synchronized yellow fever vaccination campaigns were implemented on either side of the international border by October 2020. Alongside Uganda, the Democratic Republic of Congo (DRC), and Uganda, South Sudan has participated in the Goma cross-border surveillance initiative. The initiative strengthened cross-border surveillance to mitigate the risk of cross-border spread during the 2018/ 2019 Ebola virus disease (EVD) outbreak in North Kivu and Ituri, DRC. South Sudan is also participating in intercountry meetings to strengthen regional health security. In May 2019, WHO-AFRO convened an intercountry meeting in Kigali, Rwanda, to strengthen regional health security for operational readiness and surveillance in response to the EVD outbreak in DRC. The meeting involved the four high-risk countries (i.e., Rwanda, Uganda, Burundi, and South Sudan) bordering DR Congo.

Table 4: distribution of confirmed outbreaks in South Sudan in 2019

No	Event	Location	Cases	Deaths	CFR%	Attack rate (cases per 10,000)
1	Yellow fever	Sakure	3	0	0.0%	0.5
2	Rubella	Aweil Center	35	0	0.0%	3.1
3	Rubella	Bor South	4	0	0.0%	0.2
4	Rubella	Gogrial West	5	1	20.0%	0.1
5	Rubella	Yirol East	3	0	0.0%	0.3
6	Rubella	Malakal PoC	23	0	0.0%	9.4
7	Rubella	Yirol West	19	0	0.0%	1.1
8	Rubella	Bentiu PoC	51	0	0.0%	4.9
9	Rubella	Wau PoC AA	11	0	0.0%	8.5
10	Rubella	Malakal PoC	178	0	0.0%	72.9
11	Measles	Abyei	316	0	0.0%	39.5
12	Measles	Juba	58	3	5.2%	1.0
13	Measles	Pibor	2056	9	0.4%	91.5
14	Measles	Gogrial West	156	0	0.0%	4.0
15	Measles	Mayom	23	0	0.0%	1.2
16	Measles	Aweil South	33	0	0.0%	2.9
17	Measles	Melut	9	0	0.0%	0.3
18	Measles	Gogrial East	11	0	0.0%	0.7
19	Measles	Aweil Center	23	0	0.0%	2.0
20	Measles	Malakal PoC	30	0	0.0%	12.3
21	Measles	Rumbek East	82	3	3.7%	3.7
22	Measles	Bor PoC	3	0	0.0%	15.5
23	Measles	Bentiu PoC	51	0	0.0%	4.9
24	Measles	Aweil East	19	0	0.0%	0.4
25	Measles	Wau PoC AA	436	5	1.1%	336.4
26	Measles	Renk	7	0	0.0%	0.3
27	Measles	Tonj North	20	2	10.0%	0.8
28	Measles	Tonj South	47		0.0%	3.6
29	Measles	Yambio	16	1	6.3%	0.7
30	Measles	Jur River	61	1	1.6%	3.2
31	Hepatitis E virus	Rubkona	36	1	2.8%	3.4
32	Hepatitis E virus	Lankien	1	0	0.0%	0.1
33	Hepatitis E virus	Aweil Center	1	0	0.0%	0.1
34	Hepatitis E virus	Lankien	12	0	0.0%	0.7
35	Burns (mass casualty)	Aweil North	130	36	27.7%	4.5

Performance on core functions

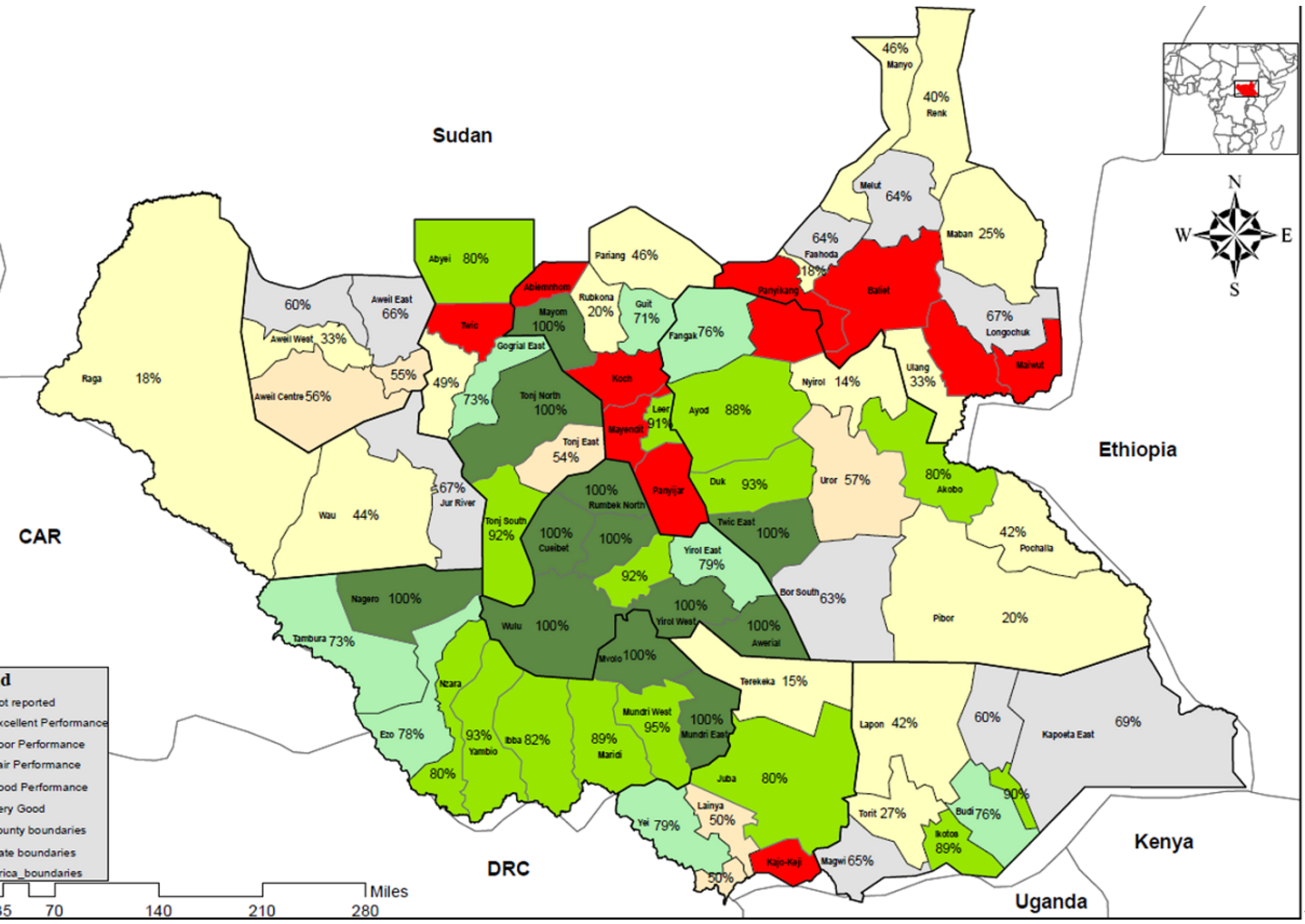
Case detection and registration: South Sudan is implementing both indicator and event-based surveillance to detect and register new cases of priority diseases or other public health events. As part of strengthening indicator-based surveillance, case definition charts and booklets have been printed and disseminated for use at health facilities. In 2019, 3,540 case definition booklets and charts were printed and distributed to the 1,260 functional health facilities. This number of case definition job-aids translates into at least three case definition job-aids distributed per functional health facility. As part of community-based surveillance, the Boma health workers (BHW) and community health workers (CHW) use simplified and translated community case definitions for case detection and registration at the community level. These simplified community case definitions are included in the case definition booklets. Indicator-based surveillance is complemented by event-based surveillance, which entails informal alerts of potentially serious public health events from the community, health facility, county, state, or national level. The log of rumors and suspect outbreaks is used for recording new alerts or suspected outbreaks. In 2019, at least one log of rumors and suspect outbreaks was distributed per functional health facility. A national toll-free center hotline exists in the call center and is used to report community alerts. Additionally, the electronic Early Warning Alert and Response (EWARS) reporting platform includes an event based platform that facilitates alert recording, verification, and risk assessment by health facility, county, and state surveillance officers and watch officers in the Public Health Emergency Operations Center (PHEOC).

In 2019, 3,184 alerts were detected and reported through the national event-based disease surveillance system using EWARS. The alerts reported in 2019 are four times higher when compared to the alerts (771) reported in 2018 (Figure 2). The significant increase in alert detection is attributed to the countrywide rollout of EWARS to the health facilities that has enhanced the detection and transmission of alerts countrywide and thus increased the capacity to detect outbreaks. Out of the 3,184 alerts reported in 2019, a total of 2,302 (72%) were verified by surveillance officers at the health facility, county, and state levels. Out of the 3,184 outbreak alerts reported, 18% were attributed to acute watery diarrhoea; 17% to suspected measles, malaria, and acute bloody diarrhoea; and 14% to acute respiratory infections.

Case confirmation and response to outbreaks and other public health emergencies: during 2019, at least 104 suspect outbreaks were reported and investigated, with 35 (33.65%) confirmed. Of the 35 confirmed outbreaks; 4 (11.4%) were due to Hepatitis E virus; 20 (57.1%) were due to measles; 9 (25.7%) were due to rubella;1 (2.9%) due to yellow fever; and 1 (2.9%) due to mass casualty (burns) (Table 4). Since the onset of the crisis in South Sudan in 2013, cholera cases have been reported every year since 2014. From 2014-2017 at least 28,676 cases, including 644 deaths (case fatality rate [CFR] 2.2%), were reported in South Sudan, but no cholera cases were confirmed in 2018, 2019, and 2020. In 2019, 105 stool samples were collected from suspect cholera cases, but they all tested negative for Vibrio cholerae after microbiological culturing and biochemical testing.

Reporting, data analysis and feedback: all priority diseases and events should be reported to the next high level either immediately, weekly, or monthly to facilitate appropriate public health action. Since the adoption of IDSR in South Sudan in 2006, routine IDSR reporting relied on a combination of paper-based, Microsoft Excel or Access datasets transmitted by email or radio calls to the next level. These approaches were fragmented, incomplete, and were associated with reporting errors and delays. Hence, in 2017, WHO, through the Global EWARS project, initiated support to the Ministry of Health and partners to streamline reporting. The support entailed modular training and technical support to facilitate the Early Warning Alert and Response System (EWARS) deployment. The EWARS is a web-based desktop and mobile application that can be rapidly configured and deployed to support early warning, alert management, and outbreak response. The EWARS mobile reporting has been deployed to support reporting in at least 1,260 functional health facilities in 10 States and three administrative areas. As part of the EWARS rollout from January 2019 to March 2020, WHO, in collaboration with the local governments and partners, has trained over 1,500 frontline health workers and distributed 21 "EWARS in a box" kits to facilitate real-time submission routine IDSR and disease outbreak reports. Each EWARS in a box kit contains 60 mobile phones with SIM cards, 25 solar power banks, and 60 EWARS quick start guides.

The completion of electronic EWARS reporting rollout has positively impacted the timeliness and completeness of weekly IDSR reporting from the health facilities. The average timeliness for submitting weekly IDSR reports from the health facilities by the end of week 39, 2020 was 78% (947 of 1,221 health facilities) compared to 54% (807 of 1,491 health facilities) by week 39, 2019, representing an increase of 24%. In the same way, the average completeness rate of reporting from the functioning health facilities across the country by week 39, 2020 was 90% (1,094 out of 1,221 functional health facilities) as compared to 54% (807 out of 1,491 functional health facilities) in week 39, 2019 representing an increase of 36%. Overall, the completeness of weekly reporting from the health facilities by county improved in 2020 when compared to 2019 and 2020 (Figure 3, Figure 4). Early warning alert and response system is programmed to generate and disseminate automated weekly national and state-level epidemiological bulletins that include indicators on the weekly reporting performance, alert management, and trends on the number of cases and deaths for the priority diseases and public health events. The Ministry of Health IDSR bulletin is produced and disseminated weekly. It contains updates on the performance of the surveillance system and updates on detection, investigation, and response to new and ongoing outbreaks and public health events. However, analysis and utilization of IDSR data is weak or nonexistent and needs to be strengthened at the



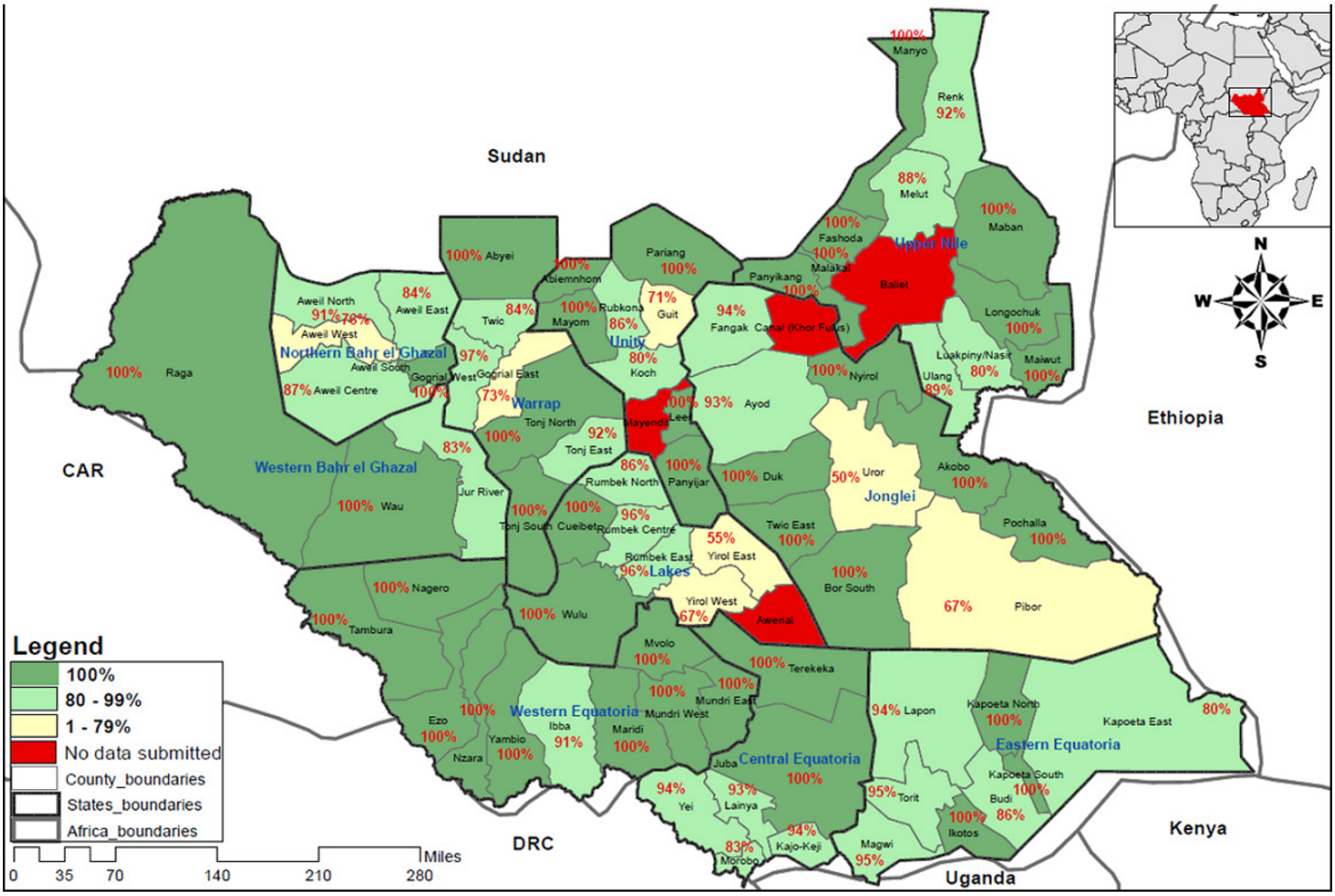


Figure 4: completeness in weekly reporting by county in week 39, 2020

county and health facility levels. All the 52 (100%) weekly bulletins for 2019 were produced and published.

Epidemic preparedness: epidemic preparedness and contingency plans are developed and updated within national and state-level efforts to improve public health security. The updated preparedness and contingency plans include cholera, epidemic meningitis, yellow fever, Rift Valley Fever, and floods. Emergency funds are incorporated into the overall MoH budget to facilitate the implementation of the plans for providing primary health care as defined in the basic package for nutrition and health (BPNH). Epidemic preparedness and response is also incorporated into humanitarian response in prioritized populations and supported using the Country-Based Pooled Funds (CBPF) and through the ongoing support to IDSR implementation by ECHO and USAID.

Response and control: with support from the WHO, the MoH has established a national multi-hazards rapid response team and state rapid response teams in each of the 10 states with regular multi-hazard training and simulation exercises. The operations of the rapid response teams are guided by standard operating procedures that define the team composition, roles of each team member, and the procedure for activation, mobilization, and deployment in response to suspect and confirmed outbreaks. Once an outbreak is confirmed, the Minister of Health designates a task force committee to coordinate the overall response in liaison with other sectors and stakeholders.

Performance on support functions: in November 2019, the South Sudan MoH adapted and adopted the third edition of IDSR technical guidelines. The guidelines are expanded to include guidance on event-based surveillance, cross-border surveillance, the use of information technology to enhance surveillance functions, guidance on surveillance in the humanitarian context, and the one-health approach. The initial training of trainers on the third edition IDSR technical guidelines have been completed. The cascade county county-level training plan has been finalized though the implementation was delayed and modified in the context of COVID-19. A dedicated national IDSR plan of action is updated annually and incorporates all the activities required to implement the support functions and strengthen the core functions at all levels. However, the plan of action is primarily donor-supported, thus raising sustainability issues in the medium to long term.

Discussion

The present study assessed performance for five core surveillance components to document the impact and experiences of deploying IDSR in a humanitarian context. Through the implementation of the IDSR strategy, South Sudan has registered significant progress towards strengthening the national disease surveillance system as demonstrated from the performance on key surveillance indicators for each of the surveillance components assessed in the present study.

Objectives of disease surveillance: in line with the IHR (2005) and the regional strategy for IDSR 2020-2030, the South Sudan Government adopted the IDSR to expand and strengthen the national surveillance and response system. Over the years, the Government adapted the requisite guidelines, expanded the priority disease list, and provided technical oversight to establish surveillance focal points, train and equip them, and monitor the implementation of IDSR functions at all levels [4]. However, the gap between country IDSR capacities and national targets is still significant, with only 26% of countries in the WHO African region having optimal IDSR implementation at the peripheral level [9]. Achieving national IDSR and IHR (2005) targets requires sustained Government stewardship, the appropriation of ample resources from the national budget to support public health security and health system strengthening, as well as social, economic, and political stability [10,11]. Since the initiation of systematic implementation of IDSR in 2009, the program has remained heavily dependent on donor resources. Therefore, it is critical that budget allocation to health security and health systems strengthening is propped up if donor investments over the recent years are to be sustained.

IDSR structure: the South Sudan Ministry of Health has established coordination structures and technical focal points to optimize IDSR functions at the community, health facility, county, state, and national level. The cross-sectoral engagement has been exploited in response to recent cholera outbreaks (2014-2017), Rift Valley Fever (2017), and COVID-19. However, these efforts are timebound and confined to the active outbreak phase. Furthermore, these efforts need to be formalized and should be extended to span the entire epidemic and emergency management cycle. Hence, as part of the NAPHS, there are plans to formalize cross-sectoral linkages with relevant line Ministries [12]. Further, the enabling laws on public health and animal health have been prioritized for enactment to facilitate public health response [12].

Existence of laboratory networks: laboratory capacities are critical to the IDSR function of detecting and confirming public health hazards [4]. South Sudan has a nascent public health laboratory system that was only inaugurated in 2014 with initial capacities to test cholera, bacterial meningitis, measles, and HIV [13]. Over the years, these capacities have been expanded to include TB, influenza and COVID-19, yellow fever, Ebola, and Marburg. Since these capacities are only available at the national level, these capacities must be extended to the sub-national level [12]. This will allow higher volumes of samples to be tested per capita, reduce the turnaround for specimen testing, and facilitate prompt response to outbreaks and public health events.

Cross border collaboration: the regional outbreaks of EVD in West Africa in 2014 spread to at least five countries in West Africa. Moreover, exported cases were reported in Europe and the United States in 2014 and 2015. Cross border EVD spread was again reported during the 2018 DRC Ebola outbreak in Ituri and North Kivu that spread to Uganda. These incidents highlight the need to enhance cross-border surveillance and response [14]. In this regard, therefore, South Sudan is currently participating in several regional cross-border initiatives. The EAC cross-border initiative is well established and involves South Sudan, Uganda, Kenya, Tanzania, Rwanda, and Burundi [15]. A total of nine cross-border surveillance zones are in place to facilitate regular emergency preparedness planning, information sharing, simulations in the EAC. South Sudan has continued to participate in the regular annual cross-border meetings since 2018 [15]. These efforts align well with the regional IDSR strategy for enhancing health security [4].

Performance on core and support functions: in line with the third edition IDSR technical guidance, South Sudan is expanding community and health facility-based surveillance using the indicator and event-based surveillance [4,9]. Boma Health Workers report alerts to the nearby health facility or use the dedicated national toll-free hotline for verification at the community level. To reinforce healthcare level capacities, the health workers training and distribution of guidelines have been undertaken. Still, health workers trained so far fall short of the optimal 2-3 trained health workers per functional health facility [4]. Gaps in training and access to requisite guidelines have been identified as impediments to IDSR implementation in Northeastern Nigeria [16]. Reporting of public health events is critical for prompt initiation of public health response. The rolling out of mobile EWARS reporting has improved the health facility IDSR reporting performance and feedback to all levels. The suboptimal IDSR reporting performance in some counties is related to the impact of impact of recurrent cycles of insecurity, hazards like floods, inadequate access to mobile telecommunications network and internet on the functionality of the health information system. The institutionalization of multidisciplinary rapid response teams has optimized investigation and response capacities at all levels. The other functions critical to optimizing the current gains entail regular emergency preparedness and response meetings, support supervision missions to state, county, and health facility level and provision of communication resources like phones, power banks and computers. South Sudan, like other countries, continues to report gaps in these key surveillance and outbreak response functions as seen from the successive of waves of outbreaks like cholera [17-19]. A notable achievement from these efforts entails cholera response from 2014-2017, with no new cholera outbreaks confirmed in South Sudan in 2018, 2019, and 2020. This success is attributed to the mapping of cholera hotspots where surveillance was enhanced in the IDSR context, case management, access to safe water and sanitation and hygiene were enhanced alongside the deployment of safe cholera vaccines [17,20].

The limitations of this study entail incomplete program and epidemiological data and the cross-sectional nature of the study that is not ideal for demonstrating the program's impact. Therefore, we used multiple sources of data to triangulate information and reduce data gaps. Also, we used standardized program performance indicators to document progress on core and support IDSR functions.

Conclusion

Since the adoption of IDSR in 2006, South Sudan has registered progress towards strengthening the national disease surveillance system. In compliance with the IHR (2005) and IDSR, the priority disease scope has been expanded, with indicator and event-based surveillance used to detect and report alerts and suspect cases. In addition, the countrywide rollout of electronic EWARS reporting has improved the reporting performance. Further, laboratory capacities continue to be strengthened following the inauguration of the National Public Health Laboratory, which now possesses capabilities for confirming priority bacterial and viral pathogens supported by a countrywide network for specimen referral. To facilitate investigation and response to suspect and confirmed outbreaks, national and state rapid response teams have over the years been trained, drilled, and deployed to support investigation and response to outbreaks of cholera, Rift Valley Fever, yellow fever, viral hemorrhagic fevers, and COVID-19. Epidemic preparedness is effectively supported through the national EP&R team. In contrast, the response to confirmed outbreaks is supported by task force committees of experts from varied disciplines and sectors using the incident management system (IMS) principles. The rollout of the third edition IDSR guidelines will further bolster this progress. The rollout will facilitate formal cross-sectoral one-health engagement, enable optimal use of EWARS and DHIS2, and allow effective cross border engagement. In collaboration with the health cluster partners, the MoH will continue using the IDSR to address fragile, vulnerable, and conflict-affected populations' surveillance and response needs. To ensure that these investments in IDSR are optimized and sustained, budget support towards strengthening the health system and surveillance system must be optimized. To address the challenge of high healthcare workers turnover, the working conditions of health workers in public health facilities must be enhanced. The NAPHS, which embodies IHR (2005) and IDSR priorities, should be implemented to enhance national and international health security. Finally, as the country works towards emerging from decades of conflict and economic downturn, donor support to the IDSR program must be sustained to reduce morbidity and mortality from priority health diseases, conditions, or events and enhance national and international health public health security.

What is known about this topic

- The integrated disease surveillance and response (IDSR) strategy provides a framework that countries in the WHO African region are using to attain core capacity requirements for the international health regulations (IHR (2005)). The member states in the African region have demonstrated that IDSR is a cost-effective strategy for effective preparedness, detection, investigation, response and control of epidemics and pandemics in the African region.

What this study adds

- Whereas the IDSR strategy has largely been used in stable settings, in this paper, we have demonstrated how the IDSR functions can be used to support Early Warning Alert and Response (EWARN) in humanitarian settings where the performance of surveillance systems is sub optimal. The sustained investment of resources towards IDSR implementation has improved the program reporting performance, thus allowing detection of major outbreaks, and averting morbidity and mortality;
- Program funding from domestic resources is critical for sustainability in the long-term.

Competing interests

The authors declare no competing interests.

Authors' contributions

JR and WJF analyzed the data and prepared the manuscript. All authors read and provided significant inputs into all drafts of the manuscript, agreed to be accountable for all aspects of the work and approved the final draft of the manuscript for publication

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Research

Contribution of Auto-Visual AFP Detection and Reporting (AVADAR) on polio surveillance in South Sudan

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Abstract

Introduction: the last wild polio virus in South Sudan was documented in 2009. Nonetheless, it was one of the last four countries in the WHO African region to be accepted as a polio-free country in June 2020. In line with this, to accelerate the polio-free documentation process, the country has piloted Auto Visual AFP Detection and Reporting (AVADAR) in three counties. This study examined the contribution of the AVADAR surveillance system to the traditional Acute Flaccid Paralysis (AFP) surveillance system to document lessons learnt and best practices.

Methods: we performed a retrospective descriptive quantitative study design to analyze secondary AVADAR surveillance data collected from June 2018 to December 2019 and stored at the WHO AVADAR server.

Results: the AVADAR community surveillance system has improved the two main AFP surveillance indicators in the piloted counties and made up 86% of the total number of true AFP cases detected in these counties. The completeness and timeliness of weekly zero reporting were 97% and 94%, respectively and maintained above the standard throughout the study, while the two main surveillance indicators in the project area were improved progressively except for the Gogrial West County. In contrast, main surveillance indicators declined in some of the none-AVADAR implementing counties.

Conclusion: the AVADAR surveillance system can overcome the logistical and remoteness barriers that can hinder the early detection and reporting of cases due to insecurity, topographical, and communication barrier in rural and hard-to-reach areas to accomplish and sustain the two main surveillance indicators, along with the completeness and timeliness of weekly zero reporting. We recommend extending this application-based surveillance system to other areas with limited resources and similar challenges by incorporating other diseases of public health concern.

Introduction

Surveillance is one of the four strategies for the global polio eradication initiative recommended by the World Health Organization (WHO). It has been proven effective in many countries that have successfully eradicated polio [1,2]. Surveillance for polio eradication heavily relies on immediate detection and notification of acute flaccid paralysis cases with a follow-up investigation and testing stool specimens in WHO accredited laboratories [3]. This determines where, when, and how Wild Polio Virus (WPV) is circulating to take appropriate response activities. It also reliably shows where transmission had been interrupted [4]. Nonetheless, in practice maintaining a high-quality AFP surveillance system is challenging in hard-to-reach and insecure areas as it is difficult routinely to access and conduct active case search, which leaves a blind spot in the area [5,6]. The country´s security crisis has contributed to a significant ongoing humanitarian crisis, with an estimated 1.67 million internally displaced persons and 2.4 million refugees leaving for safety in other countries. At the same time, 7.5 million need urgent humanitarian assistance as of October 2019 [7,8]. Years of protracted conflict, poverty, and socio-economic marginalization in South Sudan have left a significant negative impact on the population´s health, leaving the health care system in much worse conditions, which unable to address the growing and diverse needs of the people. This situation is exacerbated by the harsh climate conditions resulting in a prolonged rainy season with floods. As a result, many counties are cut off and inaccessible for over six months, adding challenges to already fragmented health services [9-11].

Like many other countries, South Sudan´s surveillance system is placed around the health facility, provided that individuals with complaints will come to the health facility, and the attending health worker will detect any suspected acute flaccid paralysis (AFP) case. Nevertheless, most of the population in South Sudan lives in rural areas with limited access to health services on top of frequent population movement, displacement and interclan conflicts [12]. Auto-Visual AFP Detection and Reporting (AVADAR) is one of the innovative mobile-based technological interventions deployed in areas with unique challenges. The use of Android smartphones has been documented in many countries in Nigeria, and Lake Chad in public health programs to improve disease surveillance and immunization [5,13]. Auto visual AFP detection and reporting was first piloted in Nigeria and found to be effective in detecting and responding to cases in areas with limited access. Following this, AVADAR has been introduced in other African countries to accelerate the regional certification process [14]. In line with this, in June 2018, South Sudan introduced- AVADAR in three counties in Gogrial West, Juba, and Terekeka, spanning two states of Central Equatoria and Warrap. This study aims to examine the contribution of the AVADAR community surveillance system to the traditional AFP surveillance system, and compare with other non-AVADAR implementing counties and document lessons learned and best practices.

Methods

Study design: we conducted a retrospective descriptive quantitative study design using the secondary AVADAR surveillance data collected from June 2018 to December 2019 and stored at the WHO AVADAR server.

Setting: the AVADAR surveillance program was established in June 2018 in three counties of Central Equatoria and Warrap states. The population of the States of Central Equatoria and Warrap is estimated to be 1,784,053 and 1,560,963, respectively (projected from the 2008 census). Central Equatorial and Warrap states consist of six and seven counties, respectively. Overall, there are 25 Payams in the piloted counties. The total population of the three pilot counties is estimated to be 1,237,894, while 582,327 are under 15 years of age. Cellular network service in these counties is provided by two telecommunication operators (i.e., MTN and Zain), while remote villages within the county may be challenging to access the network. Terekeka and Juba can be accessed by road from the national level, while a flight only accesses Warrap.

Study population: the study population includes all documented AFP cases among children under 15 years of age that have been notified by the community informants and confirmed by WHO surveillance officers as TRUE AFP cases. Any case that has not been confirmed for whatever cause was excluded.

Training of participants: at the beginning of the program, on average, 10 Community Informants (CI) were selected from 25 Payams and trained for an initial three days conducted in small groups about the principles of AVADAR application. Demonstrations, group work, and role-play sessions were used so that the CIs effectively managed the AVADAR application. A 1-day additional training was also conducted for coordinators and technical officers on data management and operational issues. At the end of the training, each participant was provided with an Android phone with the AVADAR application with SIM and a portable solar charger. Technical officers managed all phone trouble shootings from eHealth assigned at each Payam throughout the study period. Senior facilitators conducted the training from WHO, Novel T, and eHealth Africa.

The AVADAR surveillance process: AVADAR is a mobile-based technology used by community informants to detect and notify suspected cases of AFP directly from the community. The application performs four operations: i) case reporting via Short Message Service (SMS) by the CI, as well as weekly zero reports; ii) the server generates an automatic SMS to the Payam surveillance officer; iii) an automatically generated email containing the investigation's findings; iv) save data, including the dashboard, to the server. Additionally, the application has embedded video that becomes live every Monday at precisely 11:00 AM. A video with a detailed description of an AFP case runs and asks whether there is an AFP ("Yes") and has not been reported or to confirm that the informant has not seen any AFP cases ("No") throughout the week (weekly zero reports). If the CI sends a "Yes" SMS with brief data, then the server will automatically trigger an alert to the cell phone of the corresponding Payam Surveillance officer with a short description of the case. The CIs use the running video also to conduct sensitization of the community. Upon receiving notification, the Payam surveillance officer investigates and sends the result of the investigation to the server by filling out the necessary information using the Open Data Kit (ODK). This includes the Report Submission ID (RSID) that allows linking the data collected by CI. Once the result is received, the server-generated SMS will automatically share the result of the investigation with all parties involved in the program. If the case is a true AFP case, the county field supervisor collects and transports specimens per the national guidelines. At the same time, the Payam officer and the national coordinator conduct supportive supervision and monthly review meetings in collaboration with county coordinators (Figure 1). For communication, a contract was made with each of the two cellular network providers (MTN and Zain) as appropriate to allow free voice communication and upload data. The Android phones are loaded with top-ups, data bundles, and a closed user caller group that enable cheap calls between the personnel involved.

Data collection methods and analysis: we used secondary AVADAR AFP surveillance data uploaded daily on the WHO AVADAR server between June 2018 and December 2019. All AFP cases detected and reported within the study period were included. We excluded all cases that did not meet the case definitions and cases >60 days to comply with the national AFP guideline. Based on the national database for AFP, we calculated the average performance of the main surveillance indicators of none of the three counties covered by AVADAR. We then compared the result with the AVADAR implementing counties from 2014-2019. These non-AVADAR implementing counties have almost comparable characteristics to those implementing AVADAR as they are neighboring counties within the states implementing AVADAR surveillance. For further analysis, we also compared the surveillance performance of the AVADAR implementing counties before and during the implementation period. The completeness and timeliness of zero weekly reports were also compared with the set standard. The national coordinator for AVADAR regularly cleans the data, while the system automatically disables some wrong entries. Frequencies, tables, and graphs were produced using MS Excel, and the results of the analysis were compared with the surveillance performance standards set by the WHO.

Definitions of terms

Active informants: informants that reported a suspected AFP case or sent a "zero report" when no case was seen within the reporting week.

AVADAR: Auto-Visual-Acute Flaccid-Paralysis Detection and Reporting.

Community Informants (CIs): a resident of the community volunteered to be an informant for AFP.

Timeliness of weekly zero reporting: number of zero reports submitted on time.

Completeness of weekly zero reporting: total number of reporting units submitted weekly zero reports.

$$\text{Non} - \text{polio AFP rate} = \frac{\text{Number of non} - \text{polio AFP cases} < 15 \text{ years old}}{\text{total number of children} < 15 \text{ years old}} x100000$$

$$\text{Stool Adequacy} = \frac{\text{Total number of cases with 2 stool specimen collected within 14 days of onset of paralysis and good condition}}{\text{Total AFP cases reported}} x100000$$

Ethical approval and consent: administrative clearance for publication of this manuscript was provided by the Ministry of Health of South Sudan and WHO under the executive clearance (ePub-IP-00331583-EC). Moreover, the Research Ethics Review Board of the Ministry of Health provided clearance for the publication of the manuscript (MoH/RERB/D.03/2022). We used the secondary data collected and stored at the AVADAR server. Individual verbal consent was received during stool specimen collection and filling of the required information in the case-based form.

Results

Over the period of analysis, the information generated by the community informants followed and responded by the Payam Officer with close supervision and monitoring by the county Field supervisor. On the other hand, the national coordinator has managed the data and gave regular feedback to the county officers and to all concerned (Figure 1). After 21 months of the pilot study, the number of community informants that were active and sending weekly zero reports remained at 234 (93%) of the initially trained community informants. The majority of 179 (77%) of the community informants are male, 221 (94%) are literate, and 229 (98%) had lived in the Payam for > 5 years (Table 1). At the begging of the project, overall, 251 community informants were engaged and distributed along the 25 study Payams in 3 counties (Figure 2). Of the total of 20,210 weekly SMS zero reports expected over the 21 months, 19,011 weekly zero reports were received, giving completeness of weekly zero reporting of 97%, while 19,019 (94%) of the weekly zero reports were received timely. All counties achieved the set target of 80% for

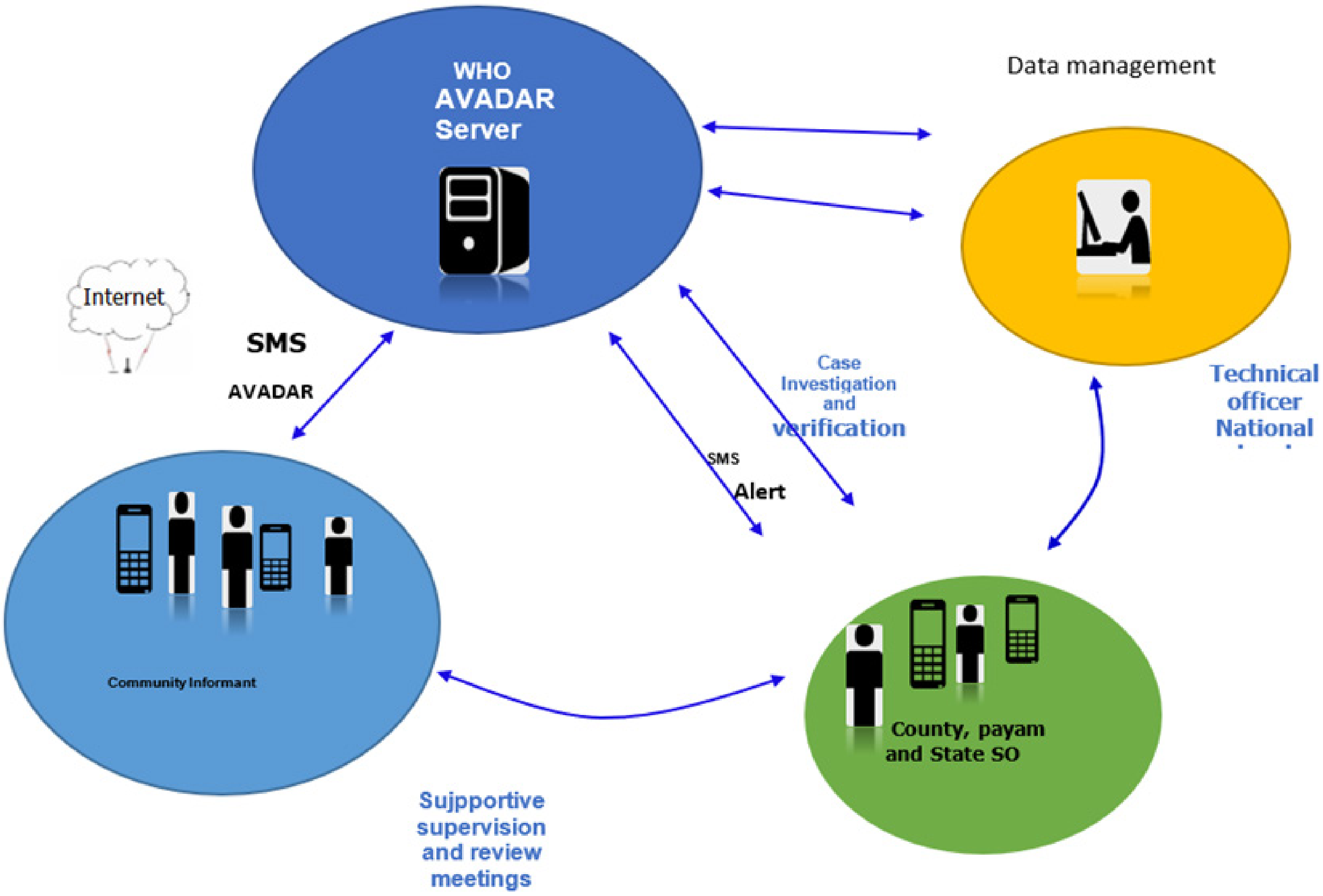

Figure 1: AVADAR community-based surveillance information and flow system 2018-2019, South Sudan

Table 1: number of community informants and project catchment population, South Sudan 2018-2019

Name of implementing County	No of implementing Payams	Community informants at the start of the project	Active informants at December 2019	% Community informants active	Sex		Education		% CIs living in the Payam	
					Male	Female	Literate	Literate	>5 years	< 5 years
Juba	10	97	84	87.6	62	22	85	0	82	3
Terekeka	6	59	54	91.5	48	6	41	13	52	2
Gogrial west	9	95	95	98.9	69	26	95	0	95	0
Total	25	251	233	92	179	54	221	13	229	5

Table 2: characteristics of AVADAR implementing counties, South Sudan, June 2018-Dec 2019

Description	Juba	Terekeka	Gogrial West	Total
Weekly report expected	7737	4719	7754	20210
weekly report received	7390	4569	7552	19511
% completeness	96	97	97	97
Weekly report expected	7737	4719	7754	20210
Report received timely	7255	4415	7349	19019
% timeliness of reporting	94	94	95	94
Suspected alerts total	322	127	129	578
Alerts investigated	321	127	129	577
% of AFP investigated with 48 hrs	100	100	100	100
AFP cases reviewed by external team				
Number of AFP cases reviewed	9	8	26	43
Number of true AFP cases	9	5	20	34
% true AFP cases	100	62	77	79
AVADAR reported cases				
Total AVADAR AFP cases	12	10	34	56
No. discarded as false AFP cases	309	117	95	521
% true AFP cases	4	9	36	11
Total non AVADAR AFP cases	8	1	0	9
Total AFP cases in the county	20	11	34	65
% AFP cases reported through AVADAR	60	91	100	86
Average days between onset and detection	4	5	6	5

Unlike other counties in the traditional surveillance, AVADAR implementing counties registered high timeliness of reporting, including investigation of cases with 48 hours

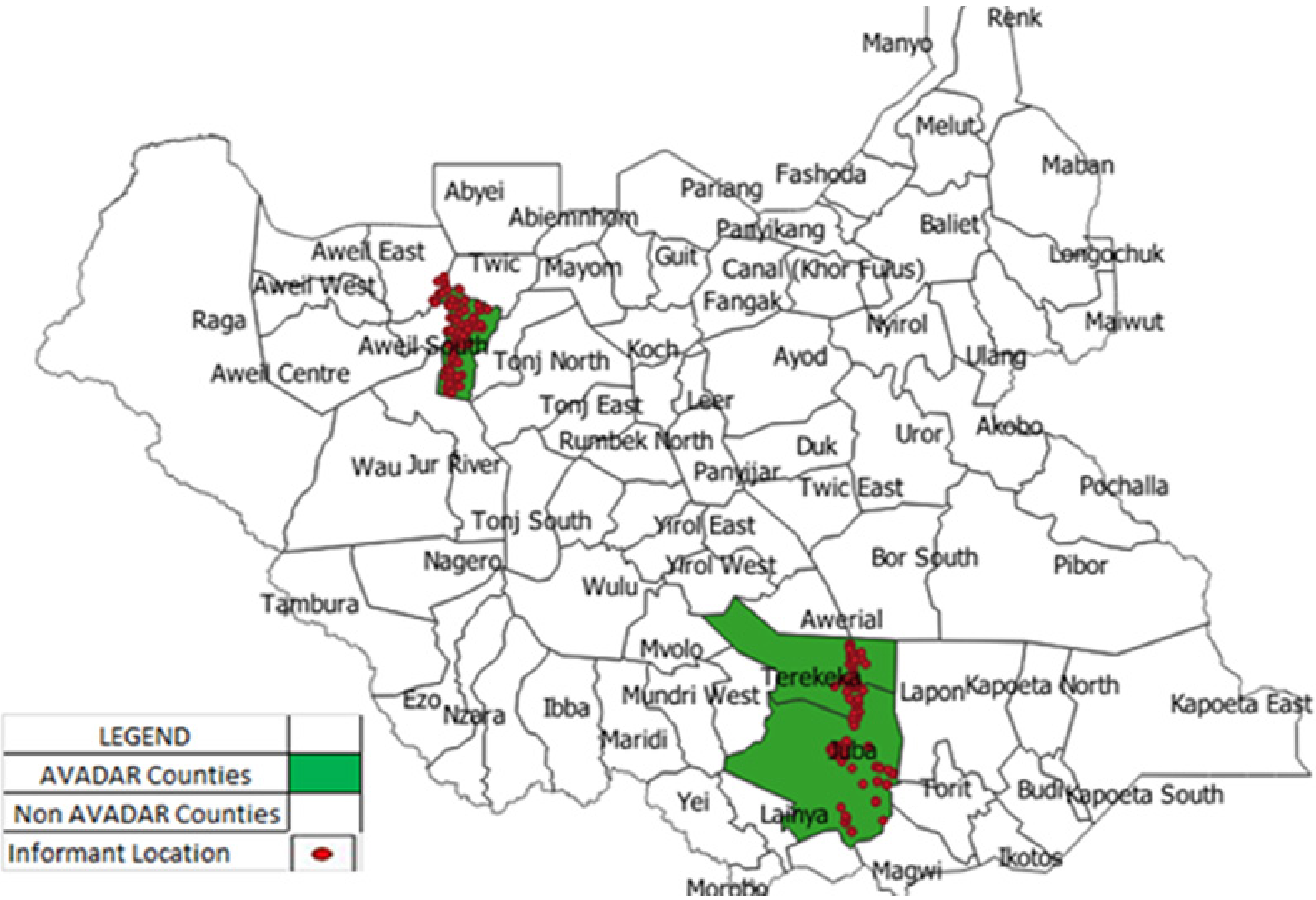

Figure 2: AVADAR implementation area 2018-2019, South Sudan

Table 3: other vaccine preventable disease reported through AVADAR community informants June 2018-Dec 2019					
County	**Number of suspected measles cases**	**Number of suspected watery diarrhea**	**Number of suspected protein/energy malnutrition**	**Number of suspected malaria cases**	**Number suspected Guinea worm cases**
Juba	3	28	57	128	0
Terekeka	2	10	15	43	0
Gogrial West	28	45	67	139	2
Total	33	83	139	310	2

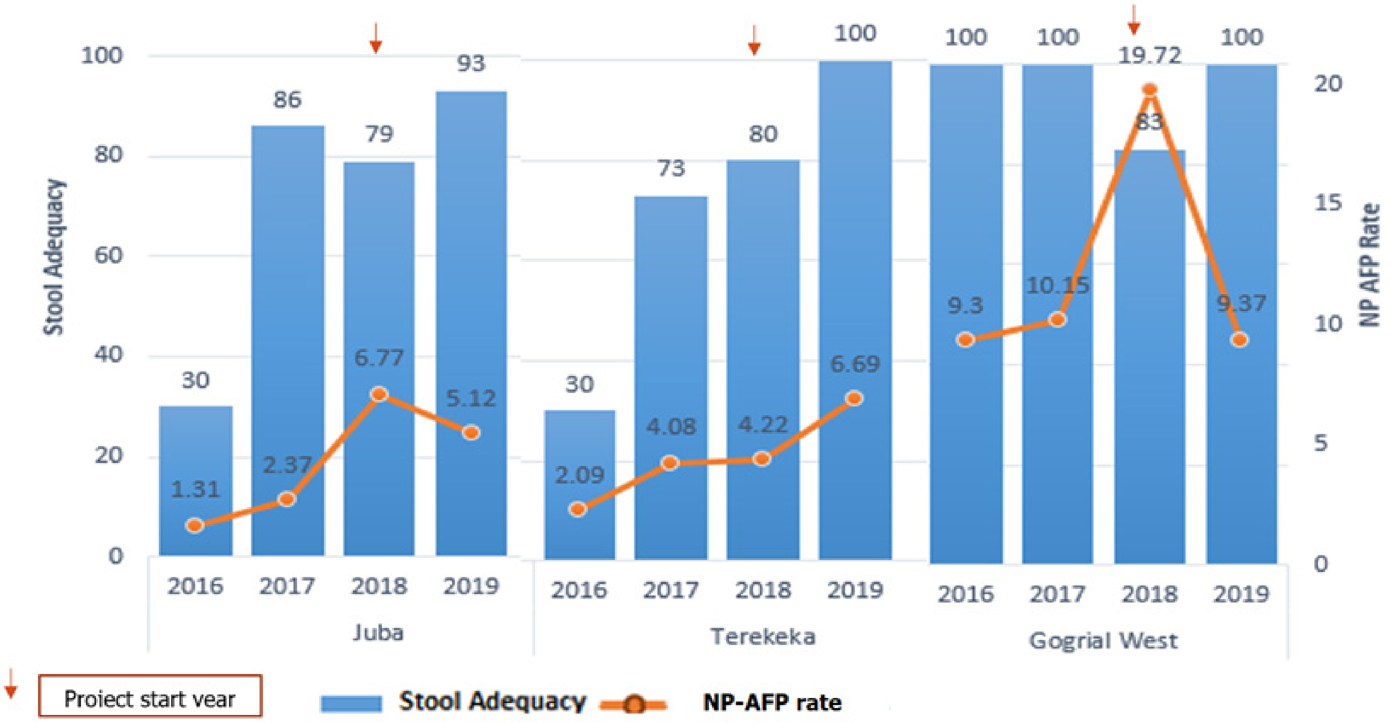

Figure 3: main surveillance indicators in AVADAR implementing counties, June 2018- Dec 2019

timely reporting and 90% for completeness of weekly zero reporting, increasing in 2019 compared to 2018 (Table 2). A total of 578 alerts for suspected cases of AFP were notified by community informants, of which 577 (99.7%) were investigated within 48 hours of notification by the Payam officers (ranged from 96% to 97%) in all the project counties. Of those suspected cases notified by community informants and investigated by officers in the three pilot counties, 56 (11%) of the cases were true AFP cases, contributing to 86% of the total AFP cases reported in the counties implementing the AVADAR surveillance system. In Terekeka and Gogrial West, the contribution of AVADAR was 97% and 100% of the cases reported, respectively, while the lowest (60%) contribution was documented in Juba County. In AVADAR implementing counties, the average number of days between the date of onset and date of detection of cases was 5 days compared to 8 days in the traditional surveillance system throughout the country (Table 2).

Before implementing AVADAR, almost all counties in the project area did not meet the two main surveillance indicators, except for Gogrial West. After the introduction of AVADAR, all counties showed a progressive improvement in the two main AFP surveillance performance indicators, most notably in Juba and Terekeka. In contrast, Gogrial West showed an increase immediately at the start of the pilot but declined and maintained the same level as before the implementation period (Figure 3). AVADAR implementing counties showed a positive linear trend of the NP-AFP rate during the pilot. Non-AVADAR implementing counties remained flat throughout the pilot. On the contrary, the stool adequacy in AVADAR implementing counties showed a flatter trend above the certification standard (80%). In comparison, non-AVADAR implementing counties showed a progressive decline in stool adequacy below the standard of stool adequacy of 80% (Figure 4). Over the study period, 567 cases of diseases of public health importance were reported through the system by the community informants. The most important reported conditions were measles, meningitis, watery diarrhea, malnutrition, and malaria (Table 3).

Discussion

The results of our study demonstrated that the two main surveillance indicators in the pilot counties are improved, and are in line with the results found in Nigeria, according to which AVADAR increased main surveillance indicators as well as detection and notification of cases [13]. This finding is also consistent with other countries´ national surveillance performance indicators [15-17]. Nonetheless, within the project counties, the results are variable. In Juba and Terekeka counties, there had been a steady increase in the NP-AFP rate, whereas, in Gogrial West, was not persistent. In the begging, it started to pick up but later it dropped to a pre-implementation level. On the other hand, stool adequacy improved in all counties. This finding supports the statement that the traditional surveillance of case detection in Gogrial West functioned relatively well even before introducing the AVADAR system. Following the introduction, the surveillance system has become more sensitive, and probably more AFP cases may have been reported beyond 2 weeks of onset due to over-sensitization.

We found a higher rate of completeness and timeliness of weekly zero reporting in the piloted countries, unlike the results of the national, traditional AFP surveillance report and the Integrated Disease Surveillance and Response weekly report [18]. However, our finding

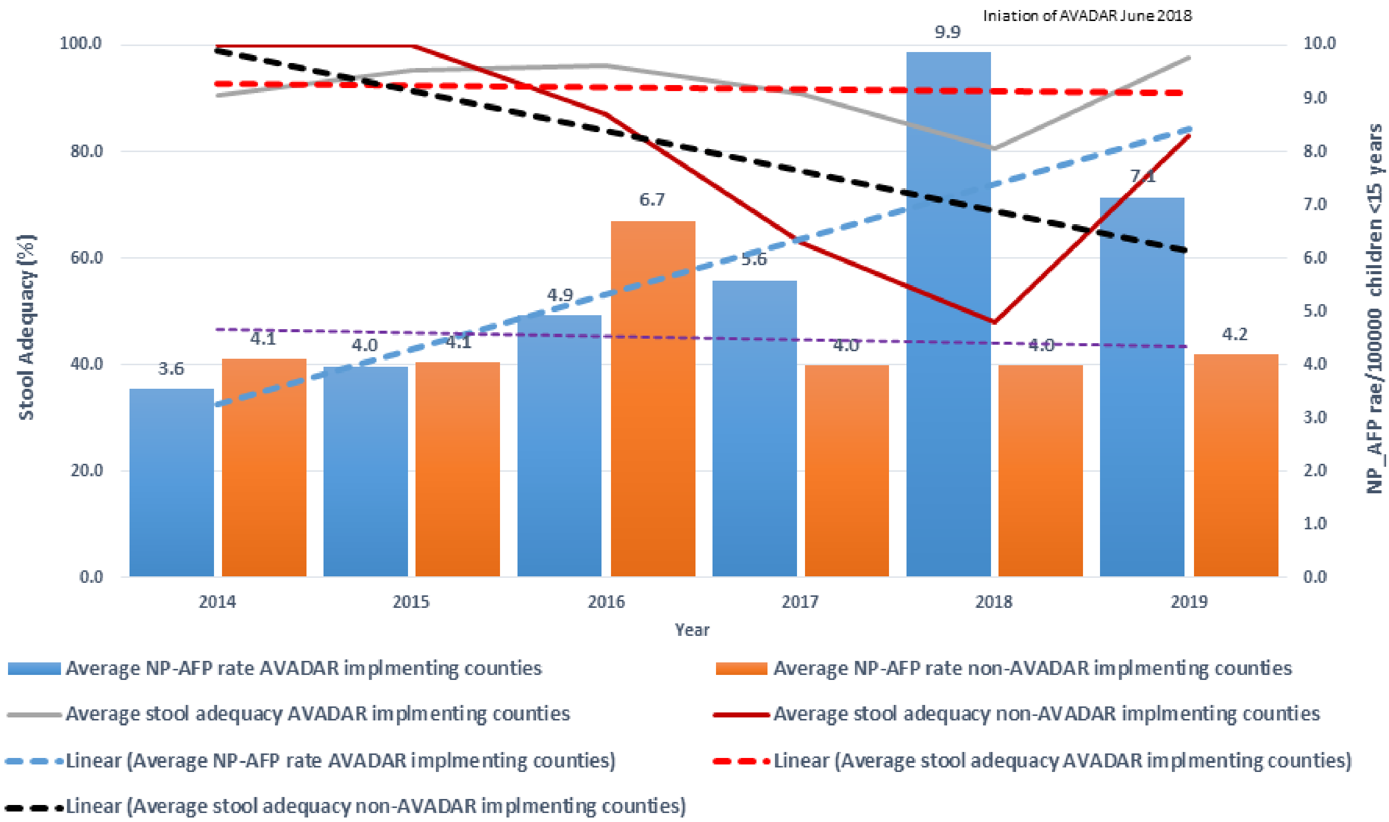

Figure 4: comparison of average two main surveillance indicators in AVADAR and non-AVADAR implementing counties 2014-2019

compares favorably with those of Faisal et al. in Nigeria, where surveillance reporting increased following the AVADAR introduction, and the WHO recommended standard for zero reporting [13,19]. The high completeness and timeliness of zero reporting in our study may have been facilitated by adding a video application embedded in the AVADAR system. The video application automatically runs every week to remind the community informants to send weekly zero reports. Furthermore, the high report may be simplified with close supervision, monitoring, and coaching of informants on top of regular monthly review meetings. On the other hand, the highest percentage of AFP cases investigated within 48 hours ties well with the WHO-recommended surveillance standard for the investigation of suspected AFP cases [19]. The high performance of our findings may have also been fueled by the presence of a fast SMS notification system by CIs and an automated alert system from the server to the Payam surveillance officers. It may also be simplified by the presence of a Payam surveillance officer in each Payam who investigates immediately once he receives an alert from the server, in which case communication, logistic, and access challenges are minimized, unlike the traditional system is suffering.

Different diseases of public health importance, including diseases under global eradication, were notified through the community informants on top of the beneficial effect of AVADAR on the improvement of the two main surveillance indicators by widening the geographic areas of case detection, resulting in an increase in case reporting and the scope of diseases reported [20]. Although many positive results were documented in implementing the AVADAR surveillance system, there were challenges in implementing the pilot. This includes poor network coverage in some study areas, which necessitated CIs walking long distances to areas where the network is good. Lack of power to regularly charge the phones due to damage to solar charges and lack of other phone accessories. However, the staff made frequent follow-ups and immediate remedies to resolve these issues.

One of the limitations of this study is that a baseline study was not done before the project's initiation to compare the results pre-and post-implementation of the pilot. However, we used the pre-pilot performance indicators to compare with current achievement both with implementing and none implementing counties, which was well documented in the AFP surveillance system. Despite these limitations, we noted that the use of AVADAR, coupled with the traditional routine surveillance system, has contributed to the successes in meeting main surveillance indicators.

Conclusion

Our study demonstrated that AVADAR could overcome the logistical and distance barriers that can impede the early detection and reporting of cases in rural and hard-to-reach areas to attain the two main surveillance indicators, along with the completeness and timeliness of weekly zero reporting. We recommend expanding the AVADAR surveillance system into other poor-performing counties with similar challenges. However, before this, an in-depth baseline assessment should be conducted, focusing on surveillance indicators, network availability, and access to power to charge phones. We also suggest integrating other diseases of public health importance into the AVADAR surveillance system by incorporating locally appropriate tools that community informants can use during active surveillance, sensitization, and reporting. This platform could also be scaled up to cover the most critical child survival initiatives like immunization (defaulter tracking) and Maternal Death Surveillance (MDS).

What is known about this topic

- AVADAR is known to increase the sensitivity of AFP surveillance in hard-to-reach and conflict-affected areas by using trained community informants;
- Acute Flaccid Paralysis (AFP) is the primary strategy for polio eradication, AVADAR supplements the traditional surveillance system by extending the surveillance network to the community level using SMS mobile-based technology and trained community informants;
- Moreover, information is sent automatically to the designated officer when the community informant finds a suspected case; this technology helps to improve the completeness, timeliness, and availability of AFP reporting.

What this study adds

- The study has systematically evaluated the use of AVADAR in South Sudan for the first time in hard-to-reach counties with poor surveillance performance and compared it with non-AVADAR implementing counties in terms of main surveillance indicators;
- The analysis of this study also finds out that AVADAR can also be used to monitor other vaccine-preventable and child survival initiatives;
- There is a significant increase in the main surveillance indicators in the piloting counties post AVADAR implementation compared to non-AVADAR counties.program reporting performance, thus allowing detection of major outbreaks, and averting morbidity and mortality;
- Program funding from domestic resources is critical for sustainability in the long-term.

Competing interests

The authors declare no competing interests.

Authors' contributions

AAT conceived, designed the study methodology, did data analysis and wrote the first draft of the article, and systematically reviewed the literature, while OOO and SM critically reviewed the manuscript and contributed to the study's design. EMOB, ANA, GAL, ALK, JMT, DPM, IMB, KKB, FN and MP reviewed in detail and gave important technical comments. All authors reviewed and approved the final version of the study.

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