Twenty Years of Integrated Disease Surveillance and Response in Sub-Saharan Africa: Challenges and Opportunities for Effective Management of Infectious Disease Epidemics

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Abstract

Background: Public health surveillance requires valid, timely and complete health information for early detection of outbreaks. Countries in Sub-Saharan Africa (SSA) adopted the Integrated Disease Surveillance and Response (IDSR) strategy in 1998 in response to an increased frequency of emerging and re-emerging diseases in the region. This systematic review aimed to analyse how IDSR implementation has embraced advancement in information technology, big data analytics techniques and wealth of data sources to strengthen detection and management of infectious disease epidemics in SSA.

Methods: Three databases were searched for eligible articles: HINARI, PubMed, and advanced Google Scholar databases. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols checklist. A total of 1,809 articles were identified using key descriptors and screened at two stages, and 45 studies met the inclusion criteria for detailed review.

Results: Of the 45 studies, 35 were country-specific, seven studies covered the region, and three studies covered 3-4 countries. A total of 24 studies assessed the IDSR core functions, while 42 studies evaluated the support functions. Twenty-three studies addressed both the core and support functions. Most of the studies involved Tanzania (9), Ghana (6) and Uganda (5). The implementation of the IDSR strategy has shown improvements, mainly in the support functions. The Health Management Information System (HMIS) has remained the main source of IDSR data. However, the HMIS system is characterised by inadequate data completeness, timeliness, quality, analysis and utilisation as well as lack of integration of data from sources other than health care facilities.

Conclusion: In most SSA, HMIS is the main source of IDSR data, characterised by incompleteness, inconsistency and inaccuracy. This data is considered to be biased and reflects only the population seeking care from healthcare facilities. Community-based event-based surveillance is weak and non-existence in the majority of the countries. Data from other systems are not effectively utilised and integrated for surveillance. It is recommended that SSA countries consider and adopt multi-sectoral, multi-disease and multi-indicator platforms that integrate the existing surveillance systems with other sources of health information to provide support to effective detection and prompt response to public health threats.

Background

Despite scientific development to strengthen the health system to protect and promote human health, Sub-Saharan Africa (SSA) continues to be confronted by longstanding, emerging, and re-emerging infectious disease threats [1,2]. The region is particularly vulnerable to infectious disease epidemics because of its favourable climatic and ecological conditions for harbouring pathogens and their vectors in an environment with high human and animal interactions [3,4]. Migration of wild animals and birds, frequent uncontrolled movements of people, commodities, animals and animal products across the
national and international borders pose additional threats in the spread of infectious diseases [5]. Moreover, civil unrest, improved travel and several socio-determinant factors have been associated with the spread of emerging infectious diseases in Africa [6-8]. Unfortunately, the region has a relatively low capacity for risk management of disease epidemics, mainly due to inadequate resources for early detection, identification, and prompt response [9]. The failure in the early detection and response to epidemics in SSA is attributed to several factors, including deficiency in the development and implementation of surveillance and response systems against infectious disease outbreaks [10].

Disease surveillance is defined as the ongoing, systematic collection, analysis, interpretation, and dissemination of data about health-related events for use in public health action to reduce morbidity and mortality and to improve health [11-14]. It serves as an early warning system in identifying emerging and re-emerging health problems and assessing their trends. Disease surveillance is also used to evaluate the impact of existing interventions, innovating and developing new public health interventions, properly allocating health resources, identifying risk factors and high-risk populations, and supporting public health research [15]. Effective disease control requires prompt and adequate action towards the reduction or elimination of existing conditions and preventing the occurrence of new ones. Such efforts can best be made when correct epidemiological and socio-ecological information reaches those required to act timely. Therefore, a functional surveillance system is critical in providing information for action on priority health events, including infectious disease epidemics [16].

Before 1998, infectious disease surveillance systems in most African countries were implemented through vertical programmes of specific diseases of national and/or international priority. Epidemiological data were collected by various programmes, mainly at health care facility levels and in outreach health service settings [17]. This situation led to fragmented and inefficient disease monitoring systems. As a potential solution, in 1998, the member states of the World Health Organisation (WHO) Regional Committee for Africa adopted a strategy namely, Integrated Disease Surveillance (IDS), with the intent to create and implement a comprehensive, integrated, action-oriented, district-focused public health surveillance for African countries [17,18]. In 2001 the strategy was renamed as Integrated Disease Surveillance and Response (IDSR) to emphasise the critical linkage between surveillance to public health action and response [19,20]. The IDSR strategy was developed in response to an increased frequency of emerging and re-emerging diseases causing high morbidity and mortality in Africa during the 1990s [17,21]. Specifically, the strategy aimed to i) integrate vertical disease surveillance systems for effective and efficient use of resources; (ii) improve the flow and use of information for detecting and responding to public health threats, and (iii) improve country capacity to detect and respond to priority public health events [17,22].

During the past 20 years, the IDSR framework has been used in 44 (94%) of the 47 countries in the WHO African region to enhance capacity on surveillance for priority diseases, conditions, and events [23-25]. Nevertheless, each national IDSR strategy defines its disease priorities, administrative processes and key actors [21]. IDSR functions are categorised into core and support functions. The core functions include identification of cases, investigation and confirmation, registration, notification/reporting the cases, data
analysis and interpretation, response to the situation, communication and provision of two-way feedback, evaluation of the intervention and prepare for emergency occurrences and are implemented at all levels of the health system [22]. The support functions include guidelines, laboratory capacity, supervision, training, resources and coordination at all levels of the health system [22,23].

In most African countries, the strategy has been implemented for about two decades, and the priority disease list required for reporting has been revised and increased [26]. Factors associated with the increase include epidemiological and non-epidemiological such as social, economic, and environmental changes [26,27]. The implementation of the strategy leveraged the purpose and scope of the International Health Regulations 2005 [21]. Having a large number of diseases monitored by the public surveillance system creates implementation challenges due to the low laboratory capacity to diagnose diseases and low utilisation of the primary health-care system, hence unconfirmed and incomplete data generated by the conventional system. Besides, the African continent has recently experienced major epidemics including those of Ebola virus disease, dengue fever, cholera, yellow fever and coronavirus disease 2019 which spread faster and further due to high global connectivity, slow detection, and might easily be missed by the routine monitoring systems.

Over the years, the IDSR has relied heavily on the routine health information system implemented at the facility and district levels of the health systems [25]. However, technology advancement and new platforms for communication such as social and news media are growing in Africa; bringing more opportunities on incorporating digital data into surveillance information, to complement the passive facility-based surveillance. Since its adoption in SSA, IDSR effectiveness and performance in the region and specific country have been studied by several authors focusing on its functions. However, assessment on the how the challenges and opportunities coming with IDSR evolvement, technology expansion and availability of other data sources relevant for detecting and managing epidemics has not been documented with certainty [14,21,23,24]. The objective of this systematic review was to analyse how IDSR implementation has embraced advancement in information technology, big data analytics techniques and wealth of data sources to strengthen detection and management of infectious disease epidemics in SSA. The gaps, challenges and opportunities identified are used to propose appropriate strategies to improve surveillance in the region.

**Methods**

**Research questions**

This review was guided by the following overarching question: Does IDSR generate information that drives early detection of, and response to infectious disease outbreaks, and that the data are of sufficient quantity and quality that matches the objectives of public health surveillance? Specific questions were: (i) What is the performance of IDSR in SSA? (ii) Has IDSR improved health data quality and utilisation during its 20 years of implementation in SSA? (iii) Has IDSR facilitated early detection and prompt
response to outbreaks in SSA? and (iv) What are the challenges and opportunities for IDSR to improve early detection and response to infectious diseases in SSA?

**Search strategy and selection criteria**

The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols (PRISMA-P) 2015 checklist [28]. Three databases, namely HINARI, PubMed, and advanced Google Scholar, were searched using Boolean operators. The search terms such as Integrated Disease Surveillance and Response (IDSR), Integrated Disease Surveillance, Health Management Information Systems (HMIS), District Health Information System (DHIS) and Sub Saharan Africa or individual member country. The search was limited to studies published in the English language between January 1998 and June 2020. An additional search was conducted using the Google search engine on the World Wide Web and hand-searching from the reference list of the screened articles. Other sources were the World Health Organization (WHO), the United States Centers for Disease Control and Prevention (CDC) and websites of individual Sub-Saharan African countries.

The review involved two-stage screening which was: Title/abstract screening and full-paper screening. The inclusion criteria used were: Study must involve at least one of the SSA country, clearly describe the evaluation of the IDSR system, focuses on at least one of the IDSR functions. The review excluded studies with abstracts without full text, not in English, reviews and newsletters. Two of the authors (IRM and LEGM) extracted eligible articles independently, and any disagreements between them on inclusion or exclusion were resolved by discussion and consensus. The linked descriptive search requests that were developed and search results from each database are presented in Table 1. Further exclusion of the article was performed during the data collection process (i.e. an article could be later excluded based on its full-text review) (Figure 1). The extracted data related to the IDSR core, and support functions' performance, challenges associated with the IDSR implementation and opportunities for improvement were summarised using thematic analysis method.
Results

Literature selection

A total of 1,809 articles were initially identified using the key search descriptors. A review of abstracts revealed a large number of articles (1,311) that were irrelevant, and some duplicates existed, which were excluded. The 498 remaining abstracts were screened further, and 412 were excluded based on the inclusion/exclusion criteria. Of the remaining 86, full-text articles were screened, and 45 studies that met the inclusion criteria selected for detailed reviews (Figure 1). Of the 45 studies, 35 were country-specific, seven studies covered the region, and three studies covered 3-4 countries. Of the 46 countries in Sub-Saharan Africa, country-specific studies were available for 20 (43.5%) countries. A total of 24 studies assessed the IDSR core functions, while 42 studies evaluated the support functions. Twenty-four studies addressed both the core and support functions. Most of the studies involved Tanzania (9) followed by Ghana (6) and Uganda (5) (Table 2).
The adoption and implementation of the IDSR strategy during the past 20 years have shown some improvements in disease surveillance activities in several countries. These include the integration of the surveillance functions of the categorical (or vertical) disease control programmes; implementation of standard surveillance, laboratory and response guidelines; improved timeliness and completeness of surveillance data, as well as increased national-level review and use of surveillance data for the response.
[23,24, 69]. However, most of the efforts to improve IDSR in SSA focused on the support functions rather than core functions.

**IDSR core functions**

Improvements in IDSR system attributes such as completeness and timeliness of data reporting after scaling up IDSR have been observed in some SSA countries including Uganda, Malawi and Ghana [37, 48, 61, 63]. Recent statistics indicated that by the end of 2017, about two-thirds (68%) of the countries in the WHO Africa Region had achieved the timeliness and completeness threshold of at least 80% of the reporting units [23]. However, over the years, the Health Management Information System (HMIS) has remained the primary data source for IDSR. The routine health information system in several SSA countries is characterised by persistent incompleteness and other data quality issues [70,71,72]. In Ethiopia and Liberia IDSR data generated through HMIS was under-utilisation as a result of poor data management and analysis skills [32,35,45]. A high level of mismatch between the entries in the HMIS registers, tally sheets and the electronic District Health Information System (DHIS2) database has also been reported in Tanzania [72,73]. Moreover, since most primary level health care facilities lack diagnostic capabilities, the generated data rely on syndromic, with low specificity [74]. Thus, despite some progress in recent years, the core IDSR data source is still weak and inaccurately reflects what is generated from the primary healthcare facility levels [72].

Health care utilisation in many low-income countries is limited; and that only a proportion of people in SSA have access to modern healthcare facilities. Several countries in SSA have reported a prevalence of between 53.0% and 87.3% of their population seeking care from conventional health care facilities. The prevalence is higher among urban than rural populations. For instance, a study in Tanzania found that despite the vast majority of the population live within 5 km of a health facility, only 40–54% of caretakers with febrile children seek healthcare [75]. Studies in Kenya reported that 76.7%-87.3% of the population sought treatment from healthcare service providers [76,77]. Like in Tanzania, relatively lower prevalence rates among rural populations of Uganda (54.1%) [78], Zambia (56.8%), [79], Ghana (55.5%) [80] and Ethiopia (43.2%) [81] seek care from conventional healthcare facilities.

**IDSR support functions**

In terms of IDSR support functions, the findings indicate that of the 47 countries in the WHO Africa Region, 94% were implementing IDSR strategy, and 45 (85%) have initiated training at the sub-national level [23]. Thirty-three (70%) of the countries were using the electronic IDSR system, and over two thirds (68%) had a feedback mechanism for sharing national surveillance data [23]. The introduction of the eIDSR using Short Message Service (SMS) for reporting weekly epidemiological data (mobile health) has proved to be a powerful tool that empowers health workers and addresses many of the barriers associated with paper-based reporting [46,59,64]. Coordination of case definitions reporting protocols across programmes was identified as a necessary step towards improving IDSR completeness and timely reporting in Uganda [64]. At the same time, the development of generic data analysis guided enhanced data quality and management in Zimbabwe [30]. In terms of key performance indicators, there was a
substantial increase in the number of countries that had adopted the IDSR guidelines and that have conducted training of healthcare workers at all levels [23].

Discussion

Challenges of IDSR in SSA

This review indicates that in most countries, data generated through the routine HMIS, which is the key source of IDSR, are rarely assessed for their quality, analysed and used to support decision-making [29]. Several studies in SSA have revealed weaknesses in case identification and recording at the primary healthcare facilities [14,24,37,57,72,82]. The quality of the data management system remains a challenge, with incomplete and inconsistent data frequently being reported at different levels of the surveillance system. Moreover, HMIS data are considered to be biased because they reflect only the population seeking care from health care facilities.

In Ethiopia, Liberia and Tanzania, assessments of the information systems have identified some data quality issues and lack of use of the generated data [45,56,72,83,84]. In a study in Ethiopia, though the surveillance system was found to be simple, useful, flexible, acceptable and representative, it lacked regular data analysis and feedback dissemination [35]. Moreover, studies in Kenya and Nigeria have indicated that there are gaps between knowledge and practice of disease surveillance among health care workers [85,86]. Incomplete data filing and inadequate organisation have been reported as an inbuilt shortcoming at all levels of IDSR in SSA countries [38,39,58,87,88]. Routine data analysis is still insufficient at facility and district levels in the majority of the countries mainly due to lack of clear guidelines on how and when to analyse data [57,58,63,72]. Reasons identified for limited data analysis included a shortage of skilled personnel, poor understanding of the use of surveillance data in planning, as well as inadequate infrastructure [72].

There are reports of a few countries (Burkina Faso, Ghana, Liberia, Uganda) that analyse and use routine HMIS data at sub-national levels in Africa [29,45]. In terms of data utilisation, in both Tanzania [56] and Liberia [45], it was found that analysis and data-use have not been given adequate attention. The studies reported under-utilisation of IDSR data at all levels of the health system as a result of poor data management and analysis skills. The culture of data analysis was lacking, and the relevance of surveillance data for decision making at sub-national levels was grossly underestimated. The use of paper-based reporting was likely to lead to severe limitations in the transmission of the data from the point of generation to a higher level [38,58]. Despite significant investment in early outbreak detection in SSA, there is very little evidence that even high utilisation of HMIS data will influence earlier detection [89].

For the integrated system to be efficient, it requires strong coordination and communication, clear organisation structure, adequate resources [90,91] and reliable sources of data. Integration may range from interconnectivity which requires simple transferring of files with basic applications to complex convergent integration which involves merging of technology with processes, knowledge, and human
IDSR strategy strives for the convergent integration route, but the majority of countries have never achieved total integration. Implementation of the strategy is partially done [23,48], and there is more focus on technical aspects than organisational, and workforce issues hence impair the performance of the systems [61,93]. Nevertheless, some countries such as Uganda have taken the actions to rectify those systemic challenges and reported improvement in the implementation [62].

**Opportunities for improving IDSR**

**Health information systems**

In SSA, several government ministries, agencies as well as academic and research institutions are involved in managing different aspects of the health information systems. The Ministries of Health run the routine HMIS as the major source of information for decision making and planning data that are generated via healthcare facilities. National Statistical Offices are responsible for most of the nation-wide household demographic and health surveys as well as census [29]. Other key health information systems include civil registration, demographic surveillance sites and research outputs [94]. Demographic surveillance sites function in several countries, but the data generated are not integrated into the national health information system because of concerns, about representativeness [29]. Besides, health research and academic institutions are increasingly generating evidence on human and animal health that could be used for disease surveillance purposes. However, most of the findings are only used for estimating national disease distribution rather than for planning national control programmes [95]. A warning of an impending epidemic can help relevant authorities and communities to prepare and take immediate actions to reduce morbidities and mortalities. However, such information is not available for planning, disease surveillance and outbreak management. It is recommended that the governments in SSA to consider establishing a national platform for infectious disease epidemics early warning system. Many of the epidemic diseases are known to be highly sensitive to long-term changes in climate and short-term fluctuations in weather. Meteorological data are made available daily by the National Meteorological Agencies, yet they are rarely used in the monitoring of the occurrence of diseases. Meteorological data can be combined with geospatially referenced data, population densities or road networks to generate estimates of environmental indicators that are relevant to infectious diseases [74].

It is critical for a good and efficient surveillance system to incorporate other sources such as mortality data from demographic surveys, environmental data, vital statistics and civil registration, antimicrobial resistance, systematic survey, meteorological data and research data. In most countries, despite an enormous amount of data generated by these systems, they run in parallel and independently, not well-coordinated, and sharing of information between them is minimal. Each of the existing systems operates its data collection and utilisation framework. Moreover, much of the information is generated outside the health sectors – making it not readily available for disease surveillance purposes. It is a fact that the innovations, including the use of Big Data and artificial intelligence, could transform infectious disease surveillance and response and complement the existing traditional disease surveillance systems and improve detection and response to epidemics [74].
**Digital disease surveillance**

Digital disease surveillance (DDS) is the use of data generated outside the public health system for disease surveillance [96]. It involves the aggregation and analysis of data available on the internet, such as search engines, social media and mobile phones, and not directly associated with patient illnesses or medical encounters. It has been shown that digital approaches in surveillance improve the timeliness and depth of surveillance information in high-income countries [96,97]. So far, DDS has demonstrated its potential in early detection and response to Ebola and COVID-19 epidemics [98-101]. Recently, DDS has been used in responding to COVID-19 through case detection, contact tracing and isolation, and quarantine in several countries [102]. In Taiwan, the government-linked immigration and customs data on travellers to the National Health Insurance data on health facility visits to identify COVID-19 suspected cases during travel to an affected area [103]. On the other hand, New Zealand and Thailand have used cell-phone location data to monitor the movement of a person's subject to quarantine or isolation orders [103]. In about 30 countries, algorithmic contact tracing through the use of a cell phone app or operating system has been deployed in response to COVID-19 pandemic [103, 104].

There is growing interest in using digital surveillance approaches to improve monitoring and control of infectious disease outbreaks. However, such applications are scarce in Africa, and few studies have shown a direct connection between DDS and public health actions. Currently, the Africa CDC is implementing a pilot programme in Ghana, Liberia, Madagascar, Nigeria, Sierra Leone and South Africa to develop digital surveillance indicators and online disease dashboards based on social media to inform infectious disease surveillance [105]. Moreover, there are on-going efforts to create real-time data sharing platforms for disease surveillance using mobile technologies that will allow centralised data management and use [106]. This is expected to strengthen real-time surveillance of infectious diseases in the continent, guide interventions, and build capacity in "Big Data" approaches for outbreak prediction, analysis and prevention.

With the proliferation of information technologies and increased rate of ownership of mobile phones in SSA, there are large amounts of data on social media blogs, chatrooms and local news reports that may provide governments and other stakeholders’ clues about disease outbreaks in time and place daily. Such data are essential raw materials for DDS. Advancements in information technology and information sharing is giving rise to a new field known as infodemiology – defined as “the science of distribution and determinants of information in an electronic medium, specifically the internet [98]. To-date, Program for Monitoring Emerging Diseases (ProMED-mail) [107] and HealthMap [108] are among the several leading efforts in digital surveillance. The World Health Organization routinely uses HealthMap, ProMED and similar systems to monitor infectious disease outbreaks and inform public health officials and the general public [109]. The key advantages of DDS include speed and volume, which may increasingly help health officials to spot outbreaks quickly and cheaply [106]

**Community event-based Surveillance**
Community-based surveillance (CBS) may be defined as the systematic detection and reporting of events of public health significance within a community by community members [110-112]. The engagement of the community has long been an essential part of both human and animal health [110-115]. CBS has played a significant role in smallpox, guinea worm and polio eradication programmes [112]. Recently, CBS was reported as an important component in response to the West African Ebola virus disease outbreak of 2014-2016 where community health workers and volunteers worked together in early detection and timely reporting to the health system [116]. With CBS, public engagement is being transformed through participatory surveillance systems that enable the community to directly report on disease events via information technology and communication tools [117]. Several CBS systems have been described and have demonstrated their accuracy and sensitivity, their ability to provide more timely measures of disease activity, and their usefulness identifying risk groups, assessing the burden of illness and informing disease transmission models [118-121]. CBS can be an important component of early warning of emerging events by engaging the communities to detect potential public health events and connecting individuals to health services [3,122-125]. In a study in Ivory Coast, following the implementation of community-based surveillance, 5-fold and 8-fold increases in reporting of suspected measles and yellow fever clusters, respectively, have been reported [122]. These findings suggest that CBS strengthened detection and reporting capabilities for several suspect priority diseases and events.

The Technical Guidelines on IDSR Guidelines [22,27] highlight the need for community-event based surveillance. This is because most of the health problems and events happen at the community level. It is through these reasons that putting a surveillance mechanism to obtain information at the community level is an added advantage to capture diseases and public health events at its early stages to allow effective preparedness and response thereby managing disease outbreaks at the source. Despite the relevance of the inclusion of community information in surveillance, by the end of 2017, of the 44 countries in the WHO Africa region, 32 (68%) had commenced CBS, and 35 (74%) had event-based surveillance [23]. However, there is only one report from Sierra Leone that data collected from the two approaches are integrated into the national IDSR system [122]. In some countries, the CBS programmes are still operating as pilot or research projects [126,127] and most cover a limited geographical area and are mainly for specific disease programmes in rural settings [122, 128].

One Health Surveillance

As part of an effective global response to diseases transmitted between animals and humans [129], there have been calls for integrating surveillance of zoonotic disease events in human and animal populations. The driving force is the fact that about three-quarters of emerging infectious diseases of humans have animal origin [130]. The concept of one health (OH) promotes the trans-sectoral collaboration between human, animal, and environmental disciplines and sectors in addressing complex health issues. The aim is to remove the traditional boundaries between disciplines and sectors and that all relevant stakeholders are involved in the definition and management of health problems [129]. Several African countries have carried out a prioritisation exercise on the zoonoses in the region. Among the diseases that were ranked high, include Anthrax, Brucellosis, Viral Haemorrhagic Fevers, Zoonotic Avian Influenza, Human African
Trypanosomiasis, Rabies and Plague [131-135]. With this approach, OH surveillance is strongly encouraged at global, national and local levels to efficiently manage health events involving humans, animals and their environment [27]. With the adoption of OH surveillance, some issues need to be considered and addressed. These include the need to define the characteristics of OH surveillance and identify the appropriate mechanisms for inter-sectoral and multi-disciplinary collaboration [90, 131].

Towards multi-sectoral and multi-indicator surveillance

The emerging and re-emerging infectious diseases in Africa underlined the urgent need for the integration of public health surveillance systems [136]. As infectious disease threats increase in SSA, effective ways of predicting outbreaks and planning for outbreak responses become increasingly important. An epidemic intelligence that encompasses activities related to early warning functions for infectious diseases of humans and animals in SSA is almost non-existent. We, therefore, propose development and adoption of a national platform for public health surveillance that is multi-sectoral, multi-disease and multi-indicator epidemic intelligence system (Figure 2). Evidence-based outbreak preparedness provides ground to streamline and concentrate our efforts towards diseases that have been documented to circulate. Among other things, outbreak preparedness entails prediction of possible epidemics with regards to the possible location of involvement, the risk and vulnerability of the population, the extent of the outbreak, its spread and socioeconomic consequences. Therefore, for any effective outbreak preparedness plan, information on prior risks is crucial in setting priorities for robust outbreak management and response plan. Research findings for decades have displayed mapping of exposure patterns and the burden of infectious diseases that have the potential to cause outbreaks in the community.

Modern technologies such as artificial intelligence and machine learning are widely applied in the analysis of a significant volume of data to assess the status and forecast future dynamics of diseases [137,138]. The prediction model is not only valuable for disease prevention and saving disability-adjusted life years, but it also saves valuable financial resources due to the high costs and resource utilisation associated with poorly predicted management techniques and costs to the health system when an outbreak happens. These emerging technologies are likely to become a powerful means of helping us collect more accurate and timely information, which in turn can lead to more effective preventive measures and improved public health practice. The techniques are expected to allow decision-makers to identify areas where the model predicts with certainty a particular risk category, to effectively target limited resources to those districts most at risk for a given season.

Conclusion

This review indicates that the majority of the countries in SSA are relying mainly on the traditional indicator-based disease surveillance utilizing data from health-care facilities. However, the traditional disease surveillance approaches face several challenges including data quality. Moreover, they miss information from populations who do not access health care or do so through informal channels, thus
unable to detect new, potentially high-impact outbreaks. Moreover, the usefulness of surveillance systems and in particular, IDSR for early detection and response to outbreaks has not been established in SSA, despite the substantial resources that have been incurred in developing and implementing the strategy. Despite the adoption of the IDSR strategy, disease surveillance remains a neglected area in most of SSA countries. Moreover, there is dearth of information on IDSR data quality, analysis and use in the detection and response of infectious disease outbreak in the region. Over the years, data-use and data-process have not been given adequate attention. Findings from this analysis indicate that future efforts to address the health information and disease surveillance systems should consider data quality, data analysis, data use and data integration. Capacity building for health workers at facility and sub-national levels in data management is critical. Equally important is to establish an effective system to improve data harmonization at facility and sub-national levels, as these are the sources of the national surveillance data.

Our review highlights untapped opportunities for integrating community-based, digital surveillance and OH surveillance and current applications that could improve public health surveillance in SSA. It is high time that the region explores and adopts the integration of several surveillance programmes into hybrid systems that couple traditional surveillance data with data from the community, research settings, as well as search queries, social media posts, and crowdsourcing. Improved performance requires the merging of current gains, strong collaboration from all stakeholders, supervision and regular evaluation of the surveillance system to identify and address challenges as they emerge. The introduction of innovative ways to further strengthen the surveillance and response system in SSA countries is therefore critical to enhance early detection and reporting of suspected cases of priority diseases, conditions and events.

To address the challenges of the existing disease surveillance system, there is a need to develop an electronic platform that will combine data from multiple relevant databases such as research programmes, HMIS, population-based surveys, digital disease surveillance, sentinel surveillance, OH surveillance and community-based surveillance initiatives to allow their interoperability. The aim is to make optimal use of community-, facility and research-based epidemiological information in preparing the community to act before a health emergency happens and provide high quality evidence to guide policy development and resource allocation at the national level. With this platform, a continuing analysis and review of scientific publications, social media, routine health data and demographic statistics can be established to feed to different units/desks. Composite indicators that comprise information from various sources can be generated, analysed and monitored. The goal is to make data readily available and help speed up the process of dissecting the information and putting programmes in place to prompt detect and stop epidemics. The platform will foster improved utilization of surveillance data for action and avoid delays in response to emergencies through linking of health indicators with other information such as climate data/products that can add value to accurately inform health risks. A multi-sectoral approach should be used where all stakeholders pursue a common strategic goal of developing a workforce that can support public health surveillance and response.
Globally, with the use of information technologies, an event-based surveillance approach is being promoted to complement the traditional “indicator-based” surveillance approach as part of the components of epidemic intelligence. It is equally important that SSA consider, adopt and use data generated from outside public health as well as research surveys. We propose SSA countries to consider and adopt the multi-sectoral, multi-disease and multi-indicator platforms that integrate the existing surveillance systems with other sources of health information to provide support to effective detection and prompt response to public health threats.

**Abbreviations**

| Abbreviation | Description                                      |
|--------------|--------------------------------------------------|
| CBS          | Community-based Surveillance                      |
| CDC          | Centres for Disease Control and Prevention        |
| DDS          | Digital disease surveillance                      |
| DHIS         | District Health Information System                |
| HIS          | Health Information Systems                        |
| HMIS         | Health Management Information System              |
| ICT          | Information and Communication Technology          |
| IDS          | Integrated Disease Surveillance                   |
| IDSR         | Integrated Disease Surveillance and Response      |
| OH           | One Health                                       |
| PRISMA-P     | Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols |
| SMS          | Short Message Service                             |
| SSA          | Sub-Saharan Africa                                |
| USSD         | Unstructured Supplementary Service Data           |
| WHO          | World Health Organization                         |

**Declarations**

**Ethics approval and consent to participate**

Not applicable.
Consent for publication

Not applicable

Availability of data and material

Not applicable

Competing interests

The authors declare that they have no competing interests

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Authors’ contributions

Both authors made substantial contributions to the conception and design of the review. IRM led data acquisition and analysis, with both authors responsible for the interpretation. IRM and JG drafted the work and LEGM provided substantial revisions. Both authors revised and approved the final version of this paper.

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Figures
Figure 1

PRISMA flow diagram for article selection
Figure 2

National Platform for a Multi-Sectoral, Multi-Disease and Multi-Indicator (3Ms) Epidemic Intelligence System

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