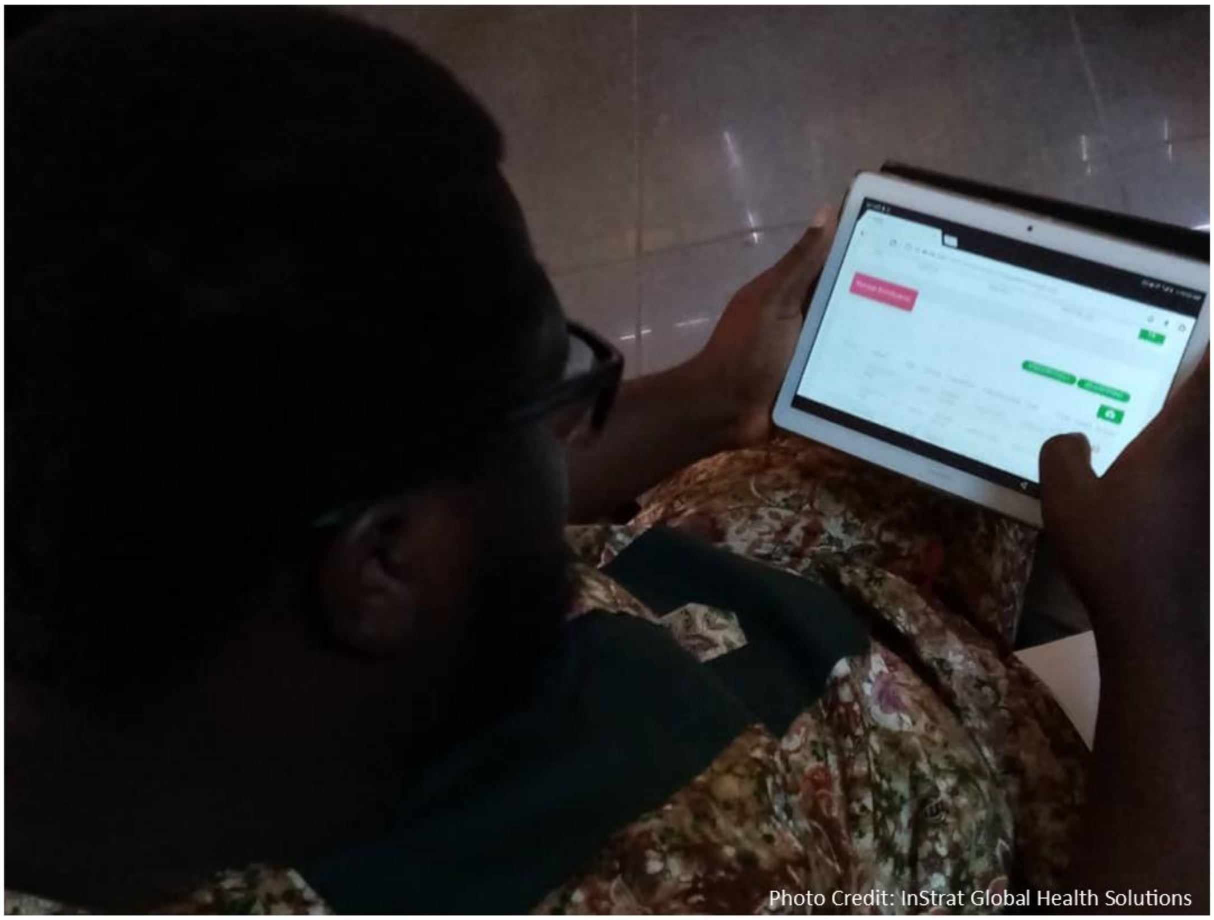
Retrospective Analysis of Electronic Vs. Manual Health Data and Disease Surveillance Records for Implications of Outbreak Management in LMICs, using Nigeria as a Case Study



Research Conducted by InStrat Global Health Solutions.

InStrat Global Health Solutions

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Acknowledgements

This project, Retrospective Analysis of Electronic Vs. Manual Health Data and Disease Surveillance Records for Implications of Outbreak Management in LMICs, using Nigeria as a Case Study, submitted in response to the 2018 call for proposals by the World Bank's Development Economics Data Group (DECDG) and the Global Partnership for Sustainable Development Data (GPSDD), is supported by the World Bank's Trust Fund for Statistical Capacity Building III (TFSCB) with financing from the United Kingdom's Foreign, Commonwealth & Development Office, the Department of Foreign Affairs and Trade of Ireland, and the Governments of Canada and Korea.

Acronyms

Acronym	Definition
APCDR	African Partnership for Chronic Disease Research
IHR	International Health Regulations
AFP	Acute Flaccid Paralysis
AVADAR	Auto-Visual AFP Detection and Reporting
BLIS	Basic Laboratory Information System
CDC	U.S. Centers for Disease Control and Prevention
CHEW	Community Health Extension Workers
CRF	Case Report Paper Forms
DHIS 2	District Health Information Software Version 2
DRC	Democratic Republic of Congo
DSNO	Disease Surveillance and Notification Officers
EDC	Electronic Data Capture
eHA	eHealth Africa
e-IDSR	Electronic Integrated Disease Surveillance & Response
EQ	Open-source Electronic Questionnaire
EWARS	Early Warning, Alert and Response System
EWORS	Early Warning Outbreak Recognition System
EWS	Early Warning System
FHIND	Foundation for Healthcare Innovation and Development
FP	Field Practitioners
GDP	Gross Domestic Product
GFT	Google Flu Trend
HRIS	Human Resource Management Information System
ICT	Information and Communication Technologies
IDI	In Depth Interviews
IDSR	Integrated Disease Surveillance and Response
InStrat	InStrat Global Health Solutions
LGA	Local Government Areas
LMIC	Lower- and Middle-Income Countries
LMIS	Logistics Management Information System
MITS	Minimally Invasive Tissue Samples
MOH	Ministry of Health
mSERS	Mobile Strengthening Epidemic Response Systems
NCDC	Nigeria Center for Disease Control
NHMIS	National Health Management Information System.
NTBLF	Nigeria Tuberculosis and Leprosy Foundation
PC	Personal Computer
PDA	Personal Digital Assistants
PHC	Primary Healthcare Center
PHE	Public Health Events

SDG	Sustainable Development Goals
SE	State epidemiologist
SMOH	State Ministry of Health
SMS	Short Messaging Service
SORMAS	Surveillance, Outbreak Response Management and Analysis System
SSA	Sub-Saharan Africa
VBD	Vector-Borne Diseases
WHO	World Health Organization

Basic Project Information

Project Title
Retrospective Analysis of Electronic Vs. Manual Health Data and Disease Surveillance Records for Implications of Outbreak Management in LMICs, using Nigeria as a Case Study.

Date of Report: October 2nd 2020

Lead Organization
InStrat Global Health Solutions facilitates improved healthcare delivery in low resource settings in Africa through the appropriate use of mobile technology. InStrat has established a track record of success by deploying mobile health technology solutions in Nigeria.

Collaborators
Foundation for Healthcare Innovation and Development (FHIND), a Nigerian not-for-profit organization formed in 2015 to promote research, innovation, and service development through sustained improvement of health systems and services, especially for vulnerable underserved groups. FHIND conducts health systems and services research, to encourage best practice and influence policy change.

Epi Afric, an African health consultancy group that focuses on improving population health through expert research and data analysis, project design and evaluation, health communication, advocacy and training.

Sustainable Development Goals (SDGs) Covered:

- SDG 3: Good Health and Wellbeing

Country: Nigeria

Data Types and Technologies:

- 2018 electronic disease surveillance and response data downloaded and analyzed on Microsoft Excel.
- 2018 paper-based records entered into Microsoft Excel and submitted to the Health Ministries.
- Electronic Survey Monkey data outputs downloaded to Microsoft Excel.

Project Objective:
To conduct a comparative analysis of electronic data management versus paper-based regimes to determine the superior method for more accurate, timely and complete disease surveillance and response data that can better inform health policy and strategy.

Executive Summary

InStrat Global Health Solutions was engaged to conduct a retrospective analysis of electronic vs. manual health data and disease surveillance records and its implications on outbreak management in Lower- and Middle-Income Countries (LMICs), using Nigeria as a case study. InStrat's technical approach and methodology was informed by the combined experience of InStrat and its partners on the use of data to inform public health policy and strategy in Nigeria as a proxy for LMICs. The project's analytical theory is that electronic data regimes will allow more accurate, timely, and complete data for health policy and strategy, especially to manage disease outbreaks.

The research study covered three Local Government Areas (LGA) in two States in Nigeria where electronic data capture systems were implemented and implemented over multiple years. The study LGAs are Epe in Lagos State with a population of 250,300 and Badagry with a population of 327,400. Lagos State, located in the South West of Nigeria, is home to over 11 million people and has the largest GDP of Nigeria's 36 States, sustained by agriculture and commerce. The other study LGA was Ifedore LGA in Ondo State with a population of 238,100. Ondo State, located in the South West of Nigeria, is home to approximately 3.5 million people and has the sixth-largest GDP of Nigeria's 36 states, sustained by agriculture, oil and natural gas.

The authors adopted a mixed methods approach to the research. The methods included Desk Research to provide the contextual underpinning of the Study; In Depth Interviews to understand policy and health professionals' experiences with both regimes; Qualitative Survey via Survey Monkey to Primary Health Care Workers, facility managers, LGA Disease Surveillance and Notification Officers (DSNO), State level policymakers. A Quantitative Statistical Analysis of publicly available data was conducted to compare the difference in the proportion of attributes derived from data generated using manual and electronic data collection methods. The team evaluated the completeness of morbidity and mortality data reported in outpatient and in-patient departments of health facilities including cases using both paper and electronic integrated disease surveillance response system forms. The accuracy assessment involved a literature review of published research comparing the accuracy of electronically captured data with paper captured data across Africa, to evaluate the relative accuracy of the two methods.

In collaboration with partner companies, InStrat acquired and accessed publicly available, de-identified, aggregate level health records and disease surveillance data in the LGAs. InStrat's Data Scouts canvassed multiple local sources including universities, libraries, research organizations, etc. to secure publicly available paper-based disease surveillance records from target LGAs.

The retrospective analysis results demonstrate the superiority of Electronic Data Collection to paper-based methods. Health workers and policy makers were unanimous in their preference for Electronic Data Capture (EDC) than Paper Based Methods. Reasons include EDC introduction resulting in increased disease reporting in the LGAs where it was piloted; increases in the number of disease surveillance reports received, interpreted, and analyzed and its support for more comprehensive reporting and decision support frameworks. From a quantitative standpoint, EDC significantly increased the quantity of data collected across diseases and the three LGAs. The completeness of electronic based surveillance was remarkably better than the paper-based methods. The Completeness Analysis showed that EDC drove a 12% increase in data completeness. The Accuracy Analysis confirmed that electronic data capture can be more accurate than the standard, paper-based data capturing processes.

Disease Outbreak Imperatives and Policy Options

The increased availability of data afforded by EDC systems will improve the capacity of LMICs to prepare for and mange outbreaks if they occur. EDCs which include electronic surveillance can help LMICs to improve integrated disease surveillance and response core indicators, including timely and complete reporting; timely outbreak detection and response; building capacity of surveillance personnel and the use of data for action. If LMICs successfully introduce and scale EDCs and electronic surveillance, critical imperatives such the use of syndromic surveillance for early disease outbreak detection and predictive analytical models and algorithms for outbreak prediction which in turn will inform disease outbreak prevention strategies.

Information and Communication Technologies (ICT) have become ubiquitous across all aspects human endeavor including business, governance, education, and commerce; just to name a few. ICT has also played a critical role in improving health care for individuals and communities by enabling new and more efficient ways of accessing, communicating, and storing information. LMICs must adopt ICT frameworks and platforms to effectively position themselves to fully take advantage of the potential that EDC and electronic surveillance systems present for proactive disease surveillance and response. Technologies that present the unifying ecosystem include the following:

- Electronic Medical Records Systems that have been adopted at hospitals and now increasingly in primary health care facilities
- Supply Chain Management Systems
- Disease Surveillance and Response
- Health Worker Training
- Human Resource Management
- Telemedicine/Telehealth
- Health Insurance Management
- Treatment Adherence/Appointment Reminders

Adoption of the above technologies will provide multiple benefits to countries that adopt them. The most immediate benefits relate to the core health systems strengthening imperative of outbreak mitigation. ICT technologies that are currently deployed in the region will help accomplish the use of syndromic surveillance for early outbreak warning; outbreak prediction using big data and artificial intelligence principles; inform vector control activities and build health worker capacity to detect, control and manage diseases and outbreaks.

Disease outbreak mitigation planning through the development of scalable mitigation strategies could also serve as valuable tools for healthcare personnel training and preparedness exercises. The most cost-effective strategies for increasing outbreak preparedness, especially in resource-constrained settings of LMICs include investments to strengthen core public health infrastructure, including water and sanitation systems; increasing situational awareness; and rapidly extinguishing sparks that could lead to pandemics. Outbreak mitigation strategies which ICT adoption will inform and strengthen include:

Strengthening Health Systems: To mitigate the impact of disease outbreaks, protect the health workforce and ensure continuity of health services during and after them, stronger health systems are needed. Critical elements include appropriate health financing systems; trained workforce that is safe and provided with personal protective equipment; access to essential medical products and technologies; business continuity planning to ensure that health systems are strong enough to withstand the increased needs and to mitigate the impacts of outbreaks.

Prevention of Vector-Borne Diseases: To prevent the transmission of Vector-Borne Diseases (VBDs), actions can be taken to protect human beings from the vectors and/or to eliminate or reduce vectors population. These actions include vector control, community engagement, and personal protection.

Nigeria has arguably transitioned from experimentation and early adoption phases of health ICT, to increasingly scaled implementation of ICT projects. The private sector has played an important role in this transition through entrepreneurial initiatives and Public, Private Partnerships which have resulted in the use of ICT across the spectrum of healthcare delivery services. Nigeria Center for Disease Control (NCDC) used an electronic active case management SORMAS since 2017 and has recently extended and SORMAS open to all priority health facilities in all Nigeria's LGAs. This as well as other private sector led initiatives including the Nigeria Tuberculosis and Leprosy Foundation (NTBLF) use of real time electronic data capture systems for tuberculosis surveillance present important examples of scalable electronic data regimes that allow for more accurate, timely, and complete data for health policy and strategy, especially to manage disease outbreaks.

Conclusion

All research conducted including the Quantitative, Qualitative, Completeness and Accuracy Analyses yielded conclusions that electronic health data management was a superior system of data collection and management for disease surveillance and response and health policy more generally. Electronic data regimes will provide frameworks through which Governments can improve Integrated Disease Surveillance and Response core indicators using electronic surveillance. As such adopting ICT technologies and platforms will help governments to adopt a more proactive footing as it relates to disease surveillance and response management. ICT will support efforts to strengthen health systems, prevent vector borne and other infectious diseases, improve health outcomes and save lives. These platforms and strategies will help LMICs that adopt them to better comply with the SDG 3: Good Health and Wellbeing.

Introduction

Research Objectives

InStrat Global Health Solutions was engaged to conduct a retrospective analysis of electronic vs. manual health data and disease surveillance records and its implications of outbreak management in LMICs, using Nigeria as a case study. InStrat's technical approach and methodology was informed by the combined experience of InStrat and its partners on the use of data to inform public health policy and strategy in Nigeria. The project's analytical theory is that electronic data regimes will allow more accurate, timely, and complete data for health policy and strategy, especially to manage disease outbreaks. To test and validate this theory InStrat acquired publicly available electronic health records and disease surveillance data from three Local Government Areas (LGA) in two States in Nigeria (Lagos State, Ondo State) where electronic health data collection has taken place in the last few years. Upon securing the data, InStrat worked with its analytical staff to cleanse the data and ensure that it is presented in tables that allow for effective analyses.

Study Setting

Lagos State, located in the South West of Nigeria, is home to over 11 million people and has the largest GDP of the 36 states, sustained by agriculture and commerce.

- Badagry LGA. Population: 327,400
- Epe LGA. Population: 250,300

Ondo State, located in the South West of Nigeria, is home to approximately 3.5 million people and has the sixth-largest GDP of the 36 states, sustained by agriculture, oil and natural gas.

- Ifedore LGA. Population: 238,100

Research Methodology

This study adopted a Mixed-Methods approach including the following:

Desk Research: InStrat reviewed ICT policies, impact evaluation reports and published articles related to Nigeria's disease surveillance and response to understand factors that shape adoption and scaleup of technologies, as well as comparisons with the status quo of paper-based reporting.

In Depth Interviews (IDIs): IDIs were conducted with PHC workers, facility managers, LGA Disease Surveillance Notification Officers (DSNO), State level policymakers. IDIs provided the interpretative context for the quantitative analytic outputs.

Qualitative Survey: A survey of comparative experiences with electronic versus paper management regimes was deployed via survey Monkey to PHC workers, facility managers, LGA DSNOs, State level policymakers.

Quantitative Statistical Analysis: In collaboration with partner companies, InStrat acquired and accessed publicly available, de-identified, aggregate level health records and disease surveillance data in LGAs. InStrat's

Data Scouts canvassed multiple local sources including universities, libraries, and research organizations to secure publicly available paper-based disease surveillance records from target LGAs. Quantitative Analyses of the data were conducted to establish the method of data collection that resulted in higher aggregate numbers and to compare the difference in proportion of attributes derived from the data generated using each method. Line and bar graphs were plotted in Excel 2013 while Z test for proportion was used employed. Statistical analysis was done using Stata 14 at 5% level of significance. Statistically significant variables were those whose p-values were below 0.05.

Completeness Analysis: This involved a retrospective research and comparative analysis of data from paper-based Integrated Disease Surveillance and Response (IDSR) Form 003 versus electronically collected data.

Accuracy Analysis: We conducted a literature review of comparisons of the accuracy of electronically captured data with paper captured data across Africa to evaluate the relative accuracy of data collected from the two methods.

Overview of Electronic Disease Surveillance in Africa and Nigeria

Following the adoption of the WHO Africa Region's Integrated Disease Surveillance and Response (IDSR) Strategy in 1998 and the International Health Regulations (IHR) in 2005, the ministries of health in the WHO African Region committed to work collaboratively to minimize the effects of public health events (PHEs) on human health, livelihood, travel and commercial trade by improving preparedness, surveillance systems and response capacity (WHO, 2014). The IDSR focuses on 40 priority diseases, sub-divided into: epidemic-prone diseases; diseases targeted for elimination; eradication of diseases of public health importance; international health regulation events and conditions. However, the reliance of the IDSR system on the manual process of capturing data on paper forms results in critical time lost. LMICs largely rely on informal and unstructured disease notification process and awareness is raised only by chance findings or upon public outcry from disease outbreaks.

Disease Surveillance and Notification in Africa

The first edition of the IDSR Technical Guidelines (2002) was widely adopted and adapted throughout the African region. Progress towards coordinated, integrated surveillance systems has been mixed, but almost every country in the region and their partners have invested human and material resources in strengthening capacities for public health systems in order to detect, confirm and respond to public health threats in time to prevent unnecessary illness, disability and death. Passive surveillance systems typically rely on data submitted to the relevant public health authority by various healthcare providers. This process is often expensive and inefficient, as substantial delays between an event and notifications are common, resulting in an incomplete account of disease emergence.

Disease Surveillance and Notification in Nigeria

Disease surveillance and notification was introduced in Nigeria in 1988 following a major outbreak of yellow fever in 1986/87 which claimed many lives in the country. In Nigeria, surveillance and notification of diseases involve the immediate notification of epidemic prone diseases, diseases targeted for elimination and eradication and monthly notification of other diseases of public health importance.

Presently in Nigeria, the collection, collation, analysis and interpretation of disease-related data in public health institutions are often incomplete and untimely partly because of poor awareness among clinicians of their importance in disease surveillance and notification activities for the prevention of infectious disease outbreaks. Many outbreaks which have occurred in Nigeria have been attributed to clinicians either not reporting or reporting late when the index cases of epidemic prone diseases present in the various health institutions across the country.

The flow of information in the IDSR system in Nigeria is from the health facility, where diseases that have epidemic potential and those which are targeted for eradication and elimination, are reported immediately to the focal persons in the health facility and thereafter to the LGA using designated IDSR reporting forms. The LGA receives data from the health facilities, collate and send to the next level which is the State Ministry of Health (SMoH). The final step in the process is the transmission of the information to the National Health Management Information System (NHMIS).

Emergence of Electronic-Based Disease Surveillance System in Africa

Annually, over 100 infectious disease outbreaks and other public health emergencies occur in the WHO Africa Region. Governments in African countries have recognized the urgent need to transition from paper-based disease surveillance methods to electronic methods. Electronic disease surveillance is a secure online framework that allows healthcare professionals and government agencies to communicate information about diseases and patterns and coordinate response to outbreaks.

There is growing interest in using digital surveillance approaches to improve monitoring and control of infectious disease outbreaks. However, LMIC applications are scarce and perhaps, as a result only few studies have shown a direct connection between the use of digital disease surveillance and public health action. As witnessed during the West African Ebola epidemic of 2014-16 and the current Corona Virus Pandemic, disease outbreaks can spread rapidly, resulting in unprecedented social and economic costs and tragic loss of life. In response to these health crises, new digital approaches to disease surveillance have emerged, aimed at speeding up the transfer of epidemiological data and increasing countries' preparedness for future outbreaks. Sierra Leone was the first country in the WHO Africa region to fully transform its national disease surveillance system from paper-based to a web-based electronic platform. As of today, electronic reporting of disease surveillance data is active in all public health facilities. The process, which was first piloted in one district in 2016, was successfully rolled out to all the 14 districts and every government health facility countrywide. The goal was to revitalize the national public health surveillance system and to speed up the response to public health events through real-time information flow. In Guinea, the Ebola outbreak of 2014-2016 demonstrated the importance of strong disease surveillance systems and the severe consequences of weak capacity to detect and respond to cases quickly. Challenges in the transmission and management of surveillance data were included in factors that contributed to the delay in detecting and confirming the Ebola outbreak. To help address this challenge, the U.S. Centers for Disease Control and Prevention (CDC), the Ministry of Health (MOH) in Guinea, the World Health Organization and other partners collaborated to strengthen the disease surveillance system through the implementation of an electronic reporting system using an open source software tool, the District Health Information Software Version 2 (DHIS 2). These efforts are part of the Global Health Security Agenda objective to strengthen real-time surveillance. In South Sudan, the Ministry of Health in collaboration with the World Health Organization (WHO) has rolled out an electronic surveillance system also called Early Warning, Alert and Response System (EWARS) to enhance the collection, management and analysis of IDSR data. A total of 108 alerts were investigated in 2017, out of which 18 outbreaks were confirmed and effectively responded to. Theses outbreaks include cholera, measles, and chickenpox. In 2002, the Uganda MOH piloted a new district level monitoring system in the south-western highlands. Incoming clinical data from health centers were collated and entered onto a district level computer and compared with a baseline of historical illness data. An anomaly measure was used to provide the index of deviation, followed by electronic reporting. This simple system detected two malaria outbreaks in Kabale, in 2005 and 2006, more than two weeks before case numbers began to peak. In 2004 an early warning system, 2 SE FAG, was established in French Guiana with the goal of detecting outbreaks of febrile illness in French soldiers, including dengue. In 2006 the system was expanded to include 25 civilian health centers that provide surveillance on sanitary conditions.

In October 2017, Nigeria Center for Disease Control implemented SORMAS after the successful pilot of an earlier prototype of this system in Nigeria in 2015. This adoption has since been expanded to cover priority health centers across Nigeria and is being used to identify coronavirus cases and their contacts for prompt isolation and treatment as required.

Electronic Disease Surveillance and Response Systems in Africa

Many online surveillance systems that function based on real-time data have been developed involving a wide range of technologies and data sources to prevent the occurrence of infectious diseases. These systems which have been implemented in several countries and are at various stages of testing and scaling adopt different approached to disease surveillance ranging from tracking of rumors to GIS tracking. These platforms also cover a variety of diseases including epidemic prone diseases. Several of them are linked to the NHMIS. These systems are continually being added to and updated.

S/N	Name of Solution	Country of Operation/Use	Description
1	Electronic Integrated Disease Surveillance & Response (e-IDSR)	Nigeria, Sierra Leone, Liberia	eIDSR enhance disease prevention and control through the capture and submission of data on epidemiologically important disease. It is a purpose-built digital data collecting and reporting tool. The tool is integrated in the national health system through its compatibility with the health information system DHIS2. In contrast to the traditional health facility paper-based system which requires data to be re-entered electronically at the district level, the e-IDSR mobile application collects and reports data from the community level up to the national level.
2	Kano Focus	Nigeria	It is an e-Learning resource center with texts, courses, and presentations.
3	Auto-Visual AFP Detection and Reporting (AVADAR)	Burkina Faso, Cameroon, Central African Republic, Chad, the Democratic Republic of Congo (DRC), Liberia, Mali, Niger, Nigeria, Sierra Leone, and South Sudan	Acute Flaccid Paralysis (AFP) is the main indicator of polio. AVADAR improves the traditional AFP surveillance systems by "widening the net" of disease reporters and using an SMS - based mobile technology to improve the completeness, timeliness, and availability of AFP reporting.
4	Child Health and Mortality Prevention Surveillance (CHAMPS)	*Bangledash*, Ethiopia, Mali, Kenya, Mozambique, South Africa, Sierra Leone	Uses digital data collection tools and Minimally Invasive Tissue Samples (MITS) to prevent future child deaths.
5	Geo-referenced Infrastructure and Demographic Data for	DRC, Nigeria, Zambia	Support the polio micro-planning work, and to serve as a base layer for GIS tracking of vaccination teams.

	Development (GRID3)		
6	SORMAS (Surveillance Outbreak Response Management and Analysis System)	Nigeria	SORMAS (Surveillance, Outbreak Response Management and Analysis System) is intended to enable digital implementation of IDSR; outbreak response management in addition to surveillance; real time data processing; and interactive task management (including contact tracing). It processes disease control and outbreak management procedures in addition to surveillance and early detection of outbreaks through real-time digital surveillance including peripheral health care facilities and laboratories. SORMAS permits early detection of outbreaks through case notifications and allows recording of rumors of potential public health significance. SORMAS presents an interactive dashboard displaying data and including epidemiological curves, mapping, and network diagrams.
7	Mobile Strengthening Epidemic Response Systems (mSERS)	Nigeria	mSERS is an SMS - based platform that automates bi-directional data collection while enabling supervision and oversight of the entire reporting process. Its functions include data gathering/collection permitting immediate case notifications, rumor notifications and weekly reporting; information feedback including information to Health Care Workers, report receipts, validation confirmations and report submission reminders; and data analysis.
8	Argus eIDSR Application	Central Africa Republic, planning implementation in Nigeria	Argus has been developed with the following concepts in mind: to facilitate IDSR for early detection, surveillance and response; to collect weekly or monthly epidemiological data; to support immediate alerts and notifications; to perform data validation at each level above; to perform data aggregation; allow reporting and exporting; assure secure SMS data transfer with hand check; to be multilingual, Argus performs three operations: i) Alert, to provide an immediate notification of cases that may signal a potential outbreak; ii) Report, to transmit Weekly and Monthly surveillance reports, and iii) Archive, to review the status of previously submitted reports.
9	Early Warning Outbreak Recognition System (EWORS)	Nigeria	EWORS detects disease outbreaks earlier than possible with traditional paper-based surveillance mechanisms. EWORS provide situational awareness during outbreaks by monitoring outbreak distribution and spread and characterizing affected populations. InStrat's E-WORs features "Indicator" (pre-diagnostic) data (e.g., syndromes) that are captured electronically allowing for real time data analysis. It has inbuilt statistical algorithms based on local baselines of syndromes or disease patterns. Such algorithms will adjust for seasonal variations in disease patterns due to weather, travel during festive occasions, etc. The statistical algorithms will

			detect unexpected elevations in indicator data and provide automated alerts or notifications to disease surveillance officers and appropriate officials of the Ministry of Health. EWORS allows real time surveillance data will be plotted on GIS heat maps and readily available to disease surveillance officers and backend information is accessible by managers via dashboards or email in real time.
10	Aether	Nigeria	Aether acts as a “helper application” that enforces strong data structure and routes data sets to the initial points of consumption. By “schematizing” the data as soon as it is available, organizations can simplify and reduce their downstream processing and the burden of interpretation. Automates the large number of repetitive data collection, cataloging, harmonization and publishing tasks associated with eHA’s ongoing projects; to move information quickly into the hands of researchers and decision-makers; to help national ministries take a rational “first step” towards interoperability by adding structure to the legacy data they already have; and to codify best practices and to reduce costs.
11	DHIS	Nigeria	DHIS2 is a tool for collection, validation, analysis and presentation of aggregate and patient-based statistical data tailored to integrated health information management activities. It is a generic tool rather than a pre-configured database application with an open meta-data model and a flexible user interface that allows the user to design the content of a specific information system. DHIS2 is intended to provide a comprehensive HIS solution based on the data warehousing principle. Customization and local adaptation is possible through the user interface. DHIS2 provides tools for data validation & improvement
12	Alert Clinic	Nigeria	The Alert clinic platform permits two-way communication and information can be entered both online and offline. Alert clinic permits scalable community level surveillance and event-based surveillance providing real time information for risk assessment and to inform public health actions
13	Basic Laboratory Information System (BLIS)	Nigeria	It is a software system that records, manages, and stores laboratory data for clinical laboratories. It captures and analyses essential laboratory data; maintenance and sharing of this data in standardized formats; real time reporting of laboratory-confirmed notifiable diseases; and synthesis of collated and analyzed data to inform policy and decision makers
14	SITAware	Nigeria	It supports assurance, governance and oversight over incidents and outbreaks (e.g. to provide at-a-glance data on number of live incidents and outbreaks, to capture information on evolution of outbreaks and actions taken), and to facilitate

			real- time data sharing between states and NCDC during major incidents. It has a clear and simple to use user interface and permits collection of data over a range of incidents (e.g. disease outbreaks, chemical and radiological incidents). Basic epidemiological data is captured along with description of incidents, actions taken and command and control arrangements. Incident information is fully updateable allowing timelines of events to be recorded and the uploading of key relevant documents.
15	Tataafo	Nigeria	Tataafo is a data mining and analytic tool. It employs text mining, analysis, and natural language processing to determine the occurrence of outbreaks based on interaction on the internet media (social, print, and other relevant media). It also retrieves trending information via configured keywords used at site searches. Key words are coined to filter information. These key words include the 41 notifiable diseases and other “street words” that connote diseases, deaths, or health conditions/events.

Source: InStrat Research, NCDC Future of Surveillance Meeting, Abuja, May 2018

Qualitative Analysis

In-Depth Interviews

In-depth interviews were carried out with selected DSNOs and facility-based Record Officers in participating health facilities; State Epidemiologists and Directors of Primary Health Care in participating States and LGAs. 29 In Depth Interviews were conducted between May 18th and June 11th, 2020. The table below details the IDI participants' roles:

Role	Number
Disease Surveillance and Notification Officers	3
Facility-based Record Officers	10
State Epidemiologists	2
Directors of Primary Health Care in participating States and LGAs.	2
Directors of Planning Research and Statistics	2

Qualitative Interview Results

The Qualitative In-Depth Interviews responses were analyzed and separated into 10 Themes. Interviewee verbatims are used extensively in this section to communicate sentiments expressed by the respondents.

1. **Benefits of EDC in Disease surveillance**
   The primary objective of electronic data capture is to facilitate faster processing of information to identify of outbreaks earlier than is possible with traditional paper-based surveillance mechanisms. Early detection and identification of abnormal increases in surveillance data is essential for the effective control of infectious disease outbreaks and subsequent spread of emerging or unexplained diseases. From increasing the quality and volume of data collected, to enabling real-time analysis of the data collected, most respondents believe that the EDC programme contributed immensely to disease surveillance in their community:

> *"It helps us notify on time. When we see any meningitis or measles case, we alert them immediately".* ***General Hospital, Ondo State***

> *"At the end of the day, it quickly helps me see how many patients we have been able to see in a day and in a week. Then at the end of the month, it makes it easier to collate the report and send".* ***Basic Health Centre, Epe.***

> *"Instead of the 20% of reports we get, it has increased to 65% in the 2 LGAs. It has helped in getting timely reports.".* ***State DSNO, Lagos State.***

> *"By giving us the tablet (computer), they increased the number of people that submit the IDSR 003 monthly report. Before I came in, they normally collected 20-25 but because of EDC, they are now able to collect up to 40-50 in a month". LGA DSNO, Badagry.*

Disease surveillance activities in Badagry and Epe were compared with other LGAs in Lagos where EDC was not being used:

> *"If you compare them with other LGAs, they have improved." LGA DSNO, Badagry.*

In Erele, a community in Ifedore LGA, during a major disease outbreak in the community, EDC tablets were deployed to the site and the use of the software proved very helpful:

> *"It was used to line list and do real time analysis of the data that was generated and so it really helped to spot the cause and with the cause identified, we were able to do the necessary community sensitization and all of the other things that brought that outbreak to an end".* ***Director of Planning Research and Statistics, Ondo State.***

EDC pick up indicators to infectious diseases and therefore identify the potential of outbreaks before they happen. A respondent believed that EDC could be used to handle Lassa Fever outbreaks in Nigeria:

> *"EDC is working and should be encouraged to stay. If we scale up to other LGAs, especially in Owo LGA, where we have Lassa fever, it is endemic in 5 LGAs, if EDC is there, I think, it will pick most of this up".* ***State DSNO, Ondo State.***

2. **Training on EDC**
Community health centers have a high rate of staff turnover and poor pay making maintenance and continuity of skills difficult, requiring constant staff training. Health workers need constant training on the proper methods for the collection of environmental and clinical specimens, as well as advanced computer skills.

> *"… there must be continuous training of the health workers. If possible, every 3 months because there is the possibility of the trained staff leaving".* ***LGA DSNO, Badagry, Lagos State.***

3. **Data Interpretation with EDC**
According to the State Epidemiologist in Ondo State, although he was not trained on how to interpret the data, he studies the analyzed data:

> *"I study what is being analyzed and I do a comparative study to what we have been having before the introduction of EDC".* ***State Epidemiologist, Ondo State.***

4. **Existing Technologies**
Other technologies existed in Ondo State:

> *"Before the launch of EDC, there was a collaborative effort with the University of Maryland via NCDC. They came around and launched mSERS. This has been working effectively."* ***State Epidemiologist, Ondo State.***

Mobile Strengthening Epidemic Response Systems (mSERS), a project supported by the US CDC through the University of Maryland, Baltimore, is a professional SMS messaging platform that facilitates the exchange of weekly disease surveillance reports between all reporting levels: Local Government Area (LGA), state and national.

5. **Technology Shyness**
   Some health workers who work in health facilities in rural areas are novices to the use of technology and may not initially display prerequisite skills to operate basic devices. Although, the health workers are used to working with paper, supervisors feel that with continuous use, they will get used to operating the EDC hardware:

   > *"Most of these people are educated but not used to operating smart phones. But we overcame that when we did the training. In fact, one of the facilities that we picked, the woman did not know how to operate it but now she is good with it. So, I think we've been able to overcome that issue of using the tablet".* ***State Epidemiologist, Ondo State.***

6. **EDC version vs Paper copy of IDSR**
   For different reasons, the respondents were unanimous in their preference for using EDC rather than paper tools to collect IDSR data:

   > *"Before now, the process of capturing our data has been so obsolete through paper and biro (pen) which is not the in thing... since the launching of EDC, I can boldly say that this has helped our epidemiological activities tremendously".* ***State Epidemiologist, Ondo State.***

   Some respondents prefer using EDC because it works faster:

   > *"This one is better. It makes reporting easier… Talk less of the one where you'll still be going through the report from day 1 to day 30".* ***Basic Health Centre, Epe LGA, Lagos State.***

   > *"Tablet is better. It is fast. If I have data that I want the DSNO to see, all I have to do is synchronize it."* ***Community Health Centre, Ondo State***

   > *"EDC is faster than paper… It sums up and gives them the results immediately.* ***LGA DSNO, Ondo State.***

   > *"Definitely, electronic data collection is better and faster, and errors are minimal, and response is definitely going to be faster because you don't take days to analyse".* ***Executive Secretary, Ondo State Primary Health Management Board.***

   Some respondents prefer EDC because the information can't be omitted:

   > *"On a paper copy you can omit some things but with the electronic copy, the information cannot be reduced".* ***Basic Health Centre, Epe LGA, Lagos State.***

   Some respondents however still use the paper copy alongside the electronic tool:

   > *"I think that the tablet is even faster than the paper, but I still do the two. I always give them the paper copy".* ***PHC Badagry, Lagos State.***

> *"The paper version can still be used for archiving purposes because it is part of the documentation for certification of any epidemic prone disease".* ***State DSNO, Ondo State.***

7. **Completeness of data**

Disparities occur when data entered into EDC is compared with data entered into the IDSR paper forms.

> *"For instance, they may send a report around 8 am but between 8 am and the end of the day, they may see about 5 cases which means they did not report those five cases for that day. But at the end of the month, when they sit down with their record, they will be able to pick everything. But they are not able to go back and resend".* ***LGA DSNO, Badagry, Lagos State.***

> *At times, they may not remember to put some number of diseases but at the end of the month when they bring all their records together, they will be able to collect more data."* ***LGA DSNO, Badagry, Lagos State.***

When a month ends on a Saturday or Sunday, respondents report that they are often unable to access the previous month's page to record data:

> *"Once a month ends on a weekend, maybe Saturday or Sunday, when we come on Monday to open the tablet, we will not have access to the previous month to record our data".* ***General Hospital, Ondo State.***

8. **Timeliness of data**

For EDC data to be effective, it must be timely, however, because it is new, there are some challenges:

> *"We had teething problems in the first three or four months on it being a new system."* ***State Epidemiologist, Lagos State.***

When this respondent was asked how EDC has helped them in collecting data for the IDSR:

> *"It helps us notify on time. When we see any meningitis or measles case, we alert them immediately".* ***General Hospital, Ondo State***

> *"There is a time limit to submit, first Wednesday of every month, that is the deadline".* ***LGA DSNO, Badagry, Lagos State.***

9. **Sustainability**

Several programs like EDC have been piloted in Ondo State, for example the mSERS program whose subscription has ended and has become the state's responsibility:

> *"…subscription they gave has been exhausted so it has now become the state's responsibility to take over from where that has stopped…You know the issue of paucity of funds."* ***State Epidemiologist, Ondo State.***

According to some respondents, EDC sustainability is a function of the incremental value it demonstrates:

> *"There is no doubt about it, there will be a progressive improvement to the program. Every effort has been put in place to see that it is extended to all the LGAs since we have been able to see the impact in the LGA where it is being piloted".* ***State Epidemiologist, Ondo State.***

> *"Today we have over 583 public health facilities in Ondo State and we are talking about deploying 363 today, even though it is still not up to the number we require. So, in terms of a usefulness, its better but the general application is where we need to scale up so that every data collector will have their tool".* ***Executive Secretary, Ondo State Primary Health Management Board.***

10. Political will

Sustainability of the EDC program is dependent on political will by all arms of government within the project State:

> *"Lagos state is very committed to ensuring that we have disease control and prevention in the state…. The state is very committed to this kind of program especially when we can get instant data reporting which is also something that the other policy makers can sit in their offices and view from the dashboard and respond effectively".* ***State Epidemiologist, Lagos State.***

> *"…some of these programs will be captured for sustainability, since we have been able to see the tremendous impact in the state preparedness and response".* ***State Epidemiologist, Ondo State.***

When a respondent was asked if he thought the government had the political will to sustain the program, he answered:

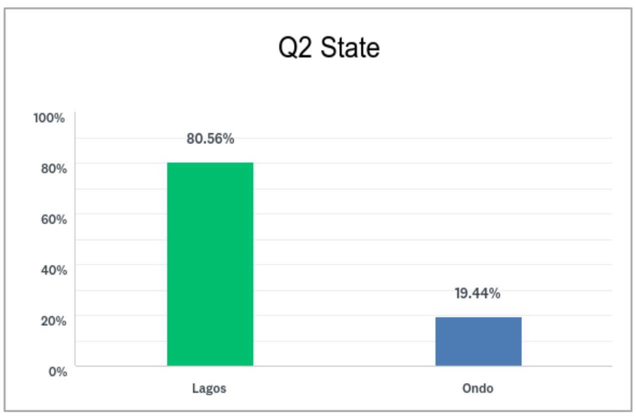
> *"For now, yes. We are hopeful that this will continue."* ***Director of planning Research and statistics, Lagos State***

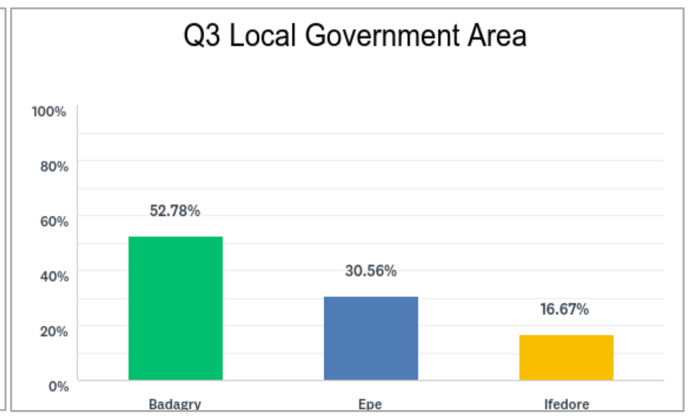
Quantitative Survey Results

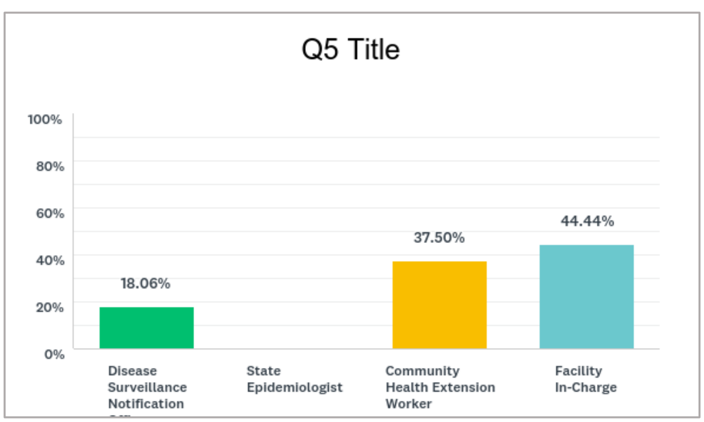
Please refer to Appendix 2 for the Qualitative Interview Survey Questionnaire.

The Qualitative Survey was sent to participants by email at midnight, Sunday, May 24th, 2020 and left open for 10 working days. The last day for responses was midnight Friday, June 5th, 2020. Below is an analysis of the online questionnaire responses:

- The Survey was administered to a total of 97 users with exposure to EDC and 71 (73%) responded
- 80.56% of the respondents were from Lagos State
- 19.44% of the respondents were from Ondo State
- 52.78% of the respondents were from Badagry LGA
- 30.56% of the respondents were from Epe LGA
- 16.67% of the respondents were from Ifedore LGA
- 18.06% of the respondents were Disease Surveillance Notification Officers (DSNO)
- 37.50% of the respondents were Community Health Extension Workers (CHEW)
- 44.44% of the respondents were Facility In-Charge
- No State Epidemiologists responded.

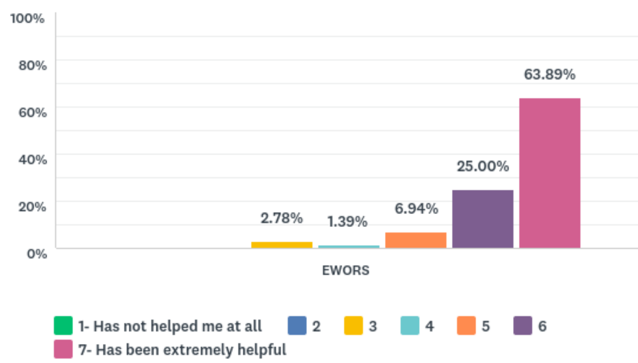






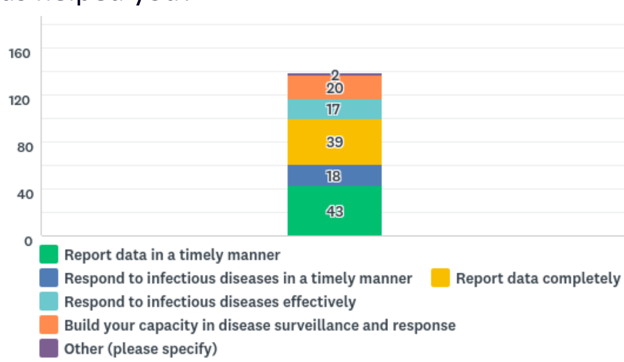
The figure below shows responses when respondents were asked to choose from a scale of 1 (Has not helped me at all) to 7 (Has been extremely helpful), how EDC has helped them improve data interpretation and response to disease outbreaks. Most of the respondents, over 80% indicated that EDC has been helpful, while 0% indicated that EDC has not helped at all.

Q6 On a scale of 1 (Has not helped me at all) to 7 (Has been extremely helpful) please rate how EDC has helped you to improve data interpretation and response to disease outbreaks.

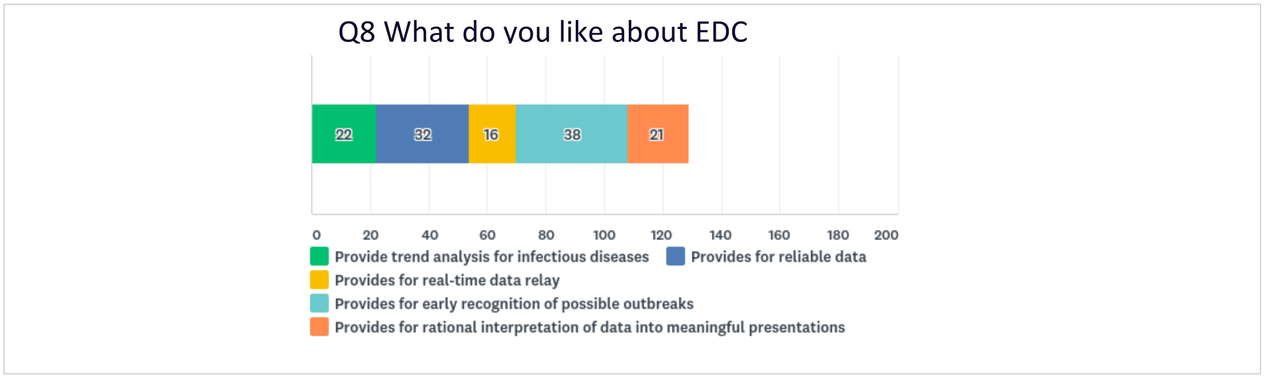


The figure below shows responses when respondents asked to describe how EDC has helped improve their work. Forty-three (30.53%) of the respondents specified that EDC has helped them 'Report data in a timely manner'; thirty-nine (27.69%) of the respondents stated that EDC has helped them 'Report data completely'; twenty (14.2%) of the respondents indicated that EDC has helped them 'Build their capacity in disease surveillance and response'; eighteen (12.78%) of the respondents indicated that EDC has helped them 'Respond to infectious disease in a timely manner; Seventeen (12.07%) of the respondents showed that EDC has helped them 'Respond to infectious disease effectively' and two (1.42%) of the respondents chose 'Other' reasons not specified.

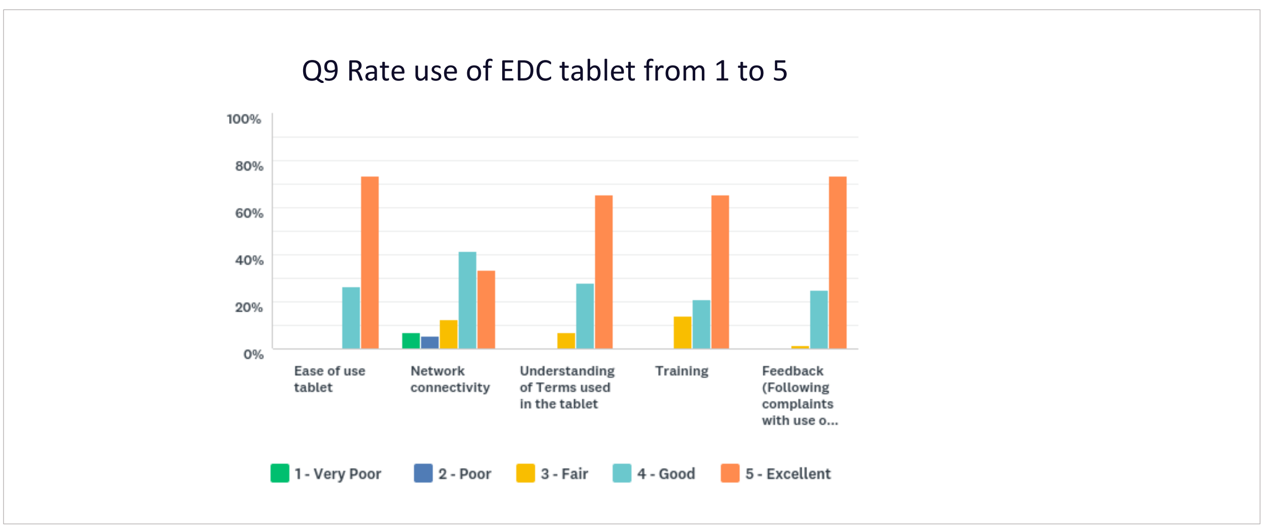
Q7 EDC has helped you?



The figure below shows respondents' answer when asked to describe what they liked about EDC. Thirty-eight (29%) of the respondents indicated that they like EDC because it 'provides for early recognition of possible outbreaks'; sixteen (12%) of the respondents like EDC because it 'provides for real-time data relay'; thirty -two (25%) of the respondents like EDC because it 'provides for reliable data'; twenty-two (17%) of the respondents like EDC because it 'provides trend analysis for infectious disease' and twenty-one (16%) of the respondents like EDC because it 'provides for rational interpretation of data into meaningful presentations'.

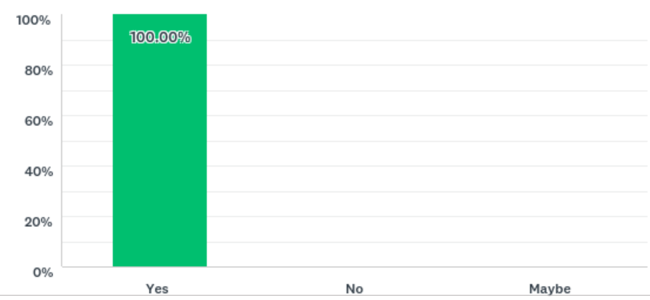


Respondents were requested to rate use of EDC tablet, from 1 (very poor) to 5 (excellent) and the figure below shows that the majority of respondents rated EDC excellent across all 5 specified areas.



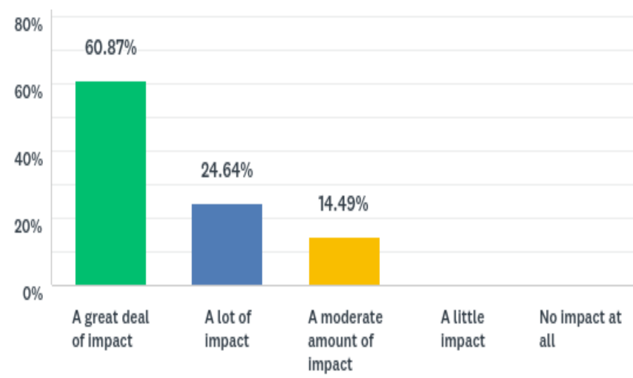
In the figure below, respondents were asked if they would be willing to recommend EDC to other health workers not currently using it and a hundred percent (100%) of the respondents said ‘yes’.

Q10 Would you recommend EDC to other health workers not currently using it?

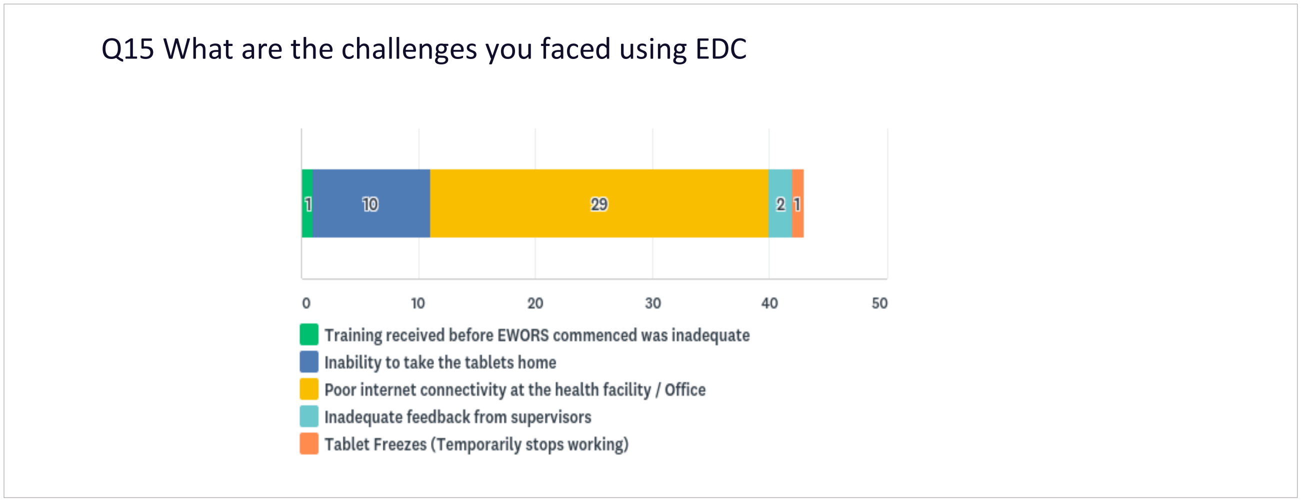


Respondents were asked to rate the level of impact EDC has had on their work. The figure below indicates that 60.87% of the respondents said that EDC has had ‘a great deal of impact’; 24.64% said that EDC has had ‘a lot of impact’ and 14.49% said EDC has had ‘a moderate amount of impact’.

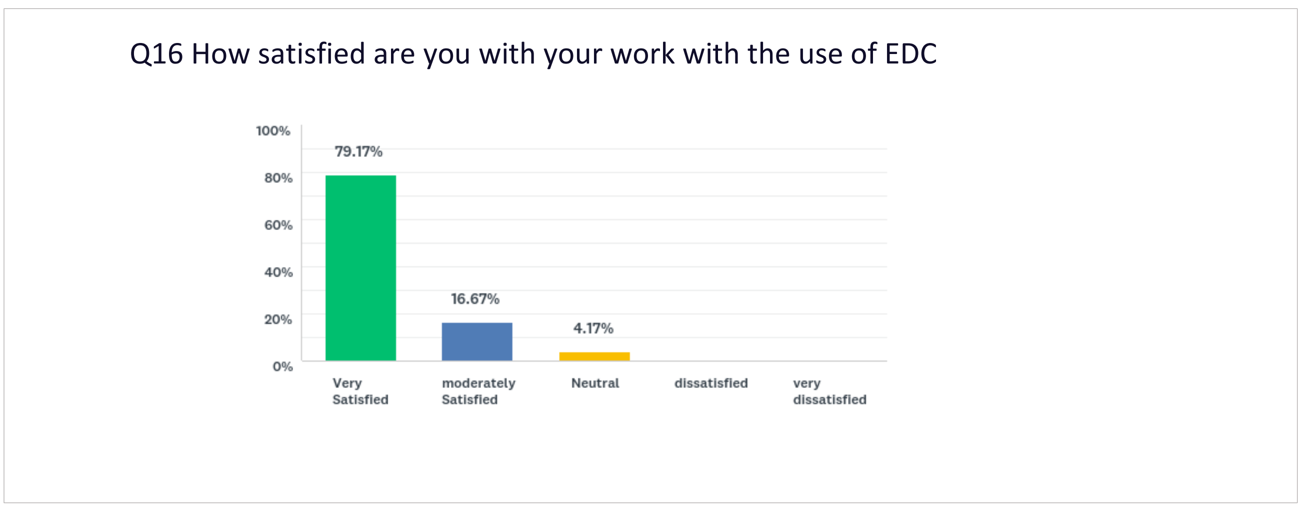
Q14 How much of an impact do you feel EDC has had on your work?



When asked what challenges they face using EDC, twenty-nine (29) respondents said the 'poor internet connectivity at the health facility/office'. Ten (10) respondents indicated, the 'inability to take the tablets home'. For two (2) respondents, it was 'inadequate feedback from supervisors'. Two other respondents said, 'inadequate training received before EDC commenced' and 'tablet freezing (temporarily stops working).



Respondents were asked to rate the level of satisfaction with their work with the use of EDC. 79.17% were very satisfied; 16.67% were moderately satisfied and 4.17% remained neutral.



Recommendations by Online Survey Respondents

1. It (EDC) should be a predictive model to notify of disease outbreaks.
2. Network (Internet) connectivity problem should be fixed.
3. Need regular training EDC
4. EDC should be expanded to other health workers
5. Other diseases should be included e.g. delivery, maternal mortality death rate.
6. By giving solar to the facility that have poor power.

Discussion

Respondents indicate that EDC helped increase disease reporting activity in the LGAs where it was piloted. EDC also helped to increase the number of disease surveillance reports received. Respondents report that EDC helped them report and analyze disease data faster. Results reveal that most of the respondents, over 80%, indicate that EDC helped them improve data interpretation and response to disease outbreaks.

Respondents indicate that disease surveillance activities are better in Badagry and Epe, where the EDC program was piloted than in other LGAs in Lagos. All respondents unanimously agree that they prefer the use of EDC over the use of paper tools for data entry. Respondents indicate that EDC has helped improve disease surveillance by ensuring timely notification and enabling real time analysis of the data received. They also reported that the use of EDC has reduced the possibility of making mistakes or omitting information during the data entry process, data can be analyzed easier and respondents do not need to spend their money-making photocopies. Some respondents however still use the paper IDSR tools for archiving purposes or compliance with mandatory paper documentation.

Quantitative Analysis

Quantitative Data Analysis Summary

The quantitative analytical comparison between electronic and paper-based data collection methods confirms that electronic data capture results in higher data volumes data across all diseases and all LGAs studies. Electronic data capture results in more comprehensive reporting and decision support frameworks. More diseases and deaths were reported using electronic methods than paper-based methods. There were 15,046 Total Cases In & Out via the electronic method or approximately three times the corresponding count of 4,793 of Paper/Manual data for all months of 2018. Similar patterns are observed across all diseases studied and across all LGAs.

State Paper / Manual Data ' 2018

	Total data submissions count (across all diseases)	Cases out patients	Cases in patients	Total cases in & out	Deaths
January	5,945	5,422	515	5,937	8
February	5,714	5,244	447	5,691	23
March	5,364	5,016	337	5,353	11
April	4,443	4,098	331	4,429	14
May	4,416	4,166	249	4,415	1
June	5,389	4,958	421	5,379	10
July	4,032	3,791	224	4,015	17
August	5,546	5,131	397	5,528	18
September	3,571	3,320	251	3,571	-
October	3,211	3,018	193	3,211	-
November	5,850	5,599	251	5,850	-
December	4,140	3,675	465	4,140	-
Average monthly data count		4,453	340	4,793	9

Electronic Data ' 2018

	Total data submissions count (across all diseases)	Cases out patients	Cases in patients	Total cases in & out	Deaths
January	35,224	33,236	1,916	35,152	72
February	27,068	25,517	1,499	27,016	52
March	22,139	20,717	1,367	22,084	55
April	14,405	12,402	1,979	14,381	24
May	11,438	10,502	918	11,420	18
June	10,829	9,894	902	10,796	33
July	13,811	12,708	1,064	13,772	39
August	9,208	8,263	890	9,153	55
September	8,595	8,047	528	8,575	20
October	14,115	13,431	656	14,087	28
November	7,493	6,987	494	7,481	12
December	6,638	6,225	413	6,638	-
Average monthly data count		13,994	1,052	15,046	34

However, a study of the statistical significance of the contribution of In Patient and Outpatient data to the total data from each reporting framework reveals a more nuanced picture. While in most cases, electronic reporting results in a statistically significant higher reporting, there were a few instances where paper methods resulted in higher statistically significant contribution. These instances occurred during periods when the absolute amounts of paper-based data were like or higher than electronically collected data for the periods. Confirmation of the reasons behind the higher statistical significance of paper-based data is limited by its very few occurrences. Statistically valid analysis requires more robust and longitudinal data sets with more occurrences to allow us to establish patterns, study and analyze them. As such further research is required to fully explain this anomaly.

Discussion of Statistical Analytical Methods

The Z test values in the tables do not indicate the occurrence of outliers. Rather, they indicate the acceptance region (when to fail to reject the Null hypothesis) or rejection region (when to reject the Null hypothesis). Using the 95% significance level, the critical value was -1.96 or 1.96. In other words, when the Z test value fell between -1.96 and 1.96, it meant there was no statistically significant difference between the proportion of attributes being compared; hence, the failure to reject the null hypothesis (i.e. the p-value was greater than or equal to 0.05). However, when the Z test value was above 1.96 or below -1.96, this implied that there was a statistically significant difference between the proportion of attributes being compared; hence, the rejection of the Null hypothesis (i.e. the p-value was less than 0.05).

We used the binomial z proportion test for the analysis. This test does not require the assumption of normal distribution. Even if the test required testing for normality of distribution (typically the case with Z test for testing the difference between the mean values of attributes, which was not what we did in our analysis), the occurrence of outliers may not have significantly affected the results because there were very large sample sizes ranging from 7,559 to 180,555.

Analysis

Overall, higher number of diseases were reported all through the year in all the LGAs using the electronic data collection method than the manual data collection method (Figure 1). However, there was a decline in the number of diseases reported from January to December using both method, with a steeper decline in the electronic data collection method which shows a sharp contrast between January (35,224) and December (6,638) cases reported.

Figure 1 below shows higher reported electronic data between January and March 2018. Reasons include possible health worker excitement from being introduced to electronic data capture using newly issued tablet computers. Some of the electronic data captured in this period also represent retrospective data from the prior December Christmas holiday, entered in January as the system did not allow workers to enter data retrospectively. This anomaly has since been fixed with a feature that allows retrospective data entry with corresponding dates.

Discussions with DSNOs suggest that the electronic data better represent their expectation of reported data suggesting that data from paper-based collection methods may be underreported. This is explained by the arcane process of collating and capturing paper based information to excel: PHCs complete paper IDSR forms monthly and submit the paper forms to the LGA officials who collate all forms from all PHCs and enter them into excel and forward the Excel files to the State officers. This process often results in missing forms, incomplete data and subject to human data entry errors. Conversely, data entered directly on the electronic systems were automatically computed at the PHC, LGA and State levels. These observations are also confirmed by the Completeness and Accuracy Analyses.

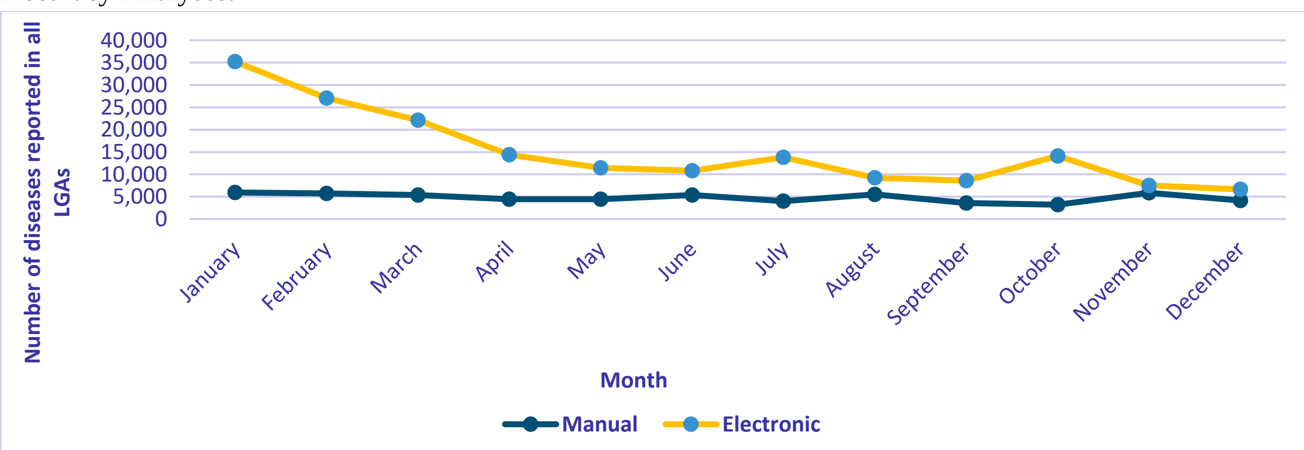


Figure 1: Monthly number of all diseases reported using the manual and electronic data collection methods in the three LGAs in 2018

Although there was a fluctuating pattern in the number of deaths reported in all the LGAs using both methods of data collection, more deaths were reported using the electronic data collection method than the manual method. Similar to the trend in the number of diseases reported in Figure 1, there was an overall decrease in the number of reported deaths from January to December using both methods, with the electronic method showing a steeper decrease from over 70 deaths in January to zero death in December (Figure 2). The higher electronic reporting rates in January to March is explained by the combined impact of health worker excitement at being introduced to electronic data capture using newly issued program devices and the entry of some of the December date in January.

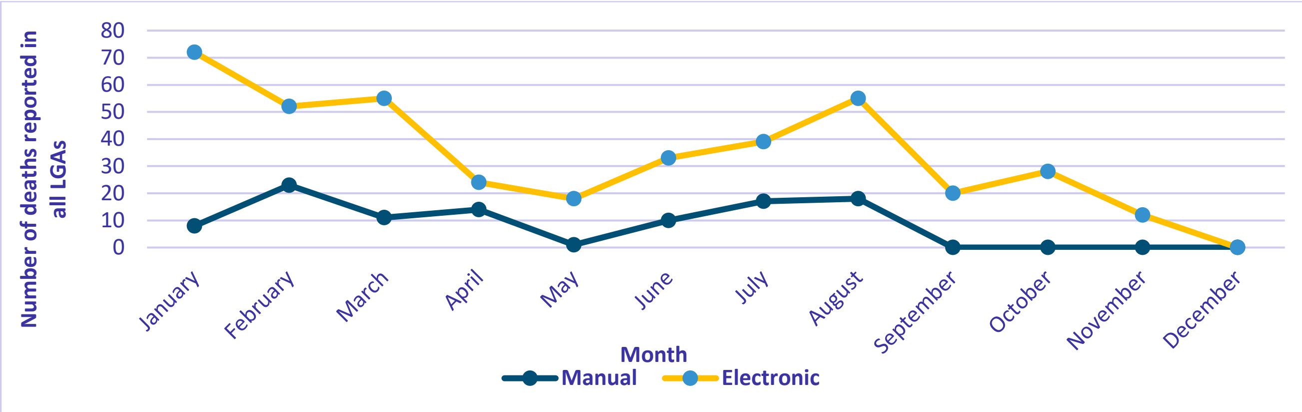


Figure 2: Monthly number of deaths reported using the manual and electronic data collection methods in the three LGAs in 2018

In Figure 3, more diseases were reported using the electronic data collection method compared with the manual method. Specifically, Badagry LGA reported the highest number of diseases using both methods and this was followed by Epe LGA. The trend in the diseases reported using the electronic method shows a gradual decline from January to December in all the LGAs.

Number of diseases reported by LGAs

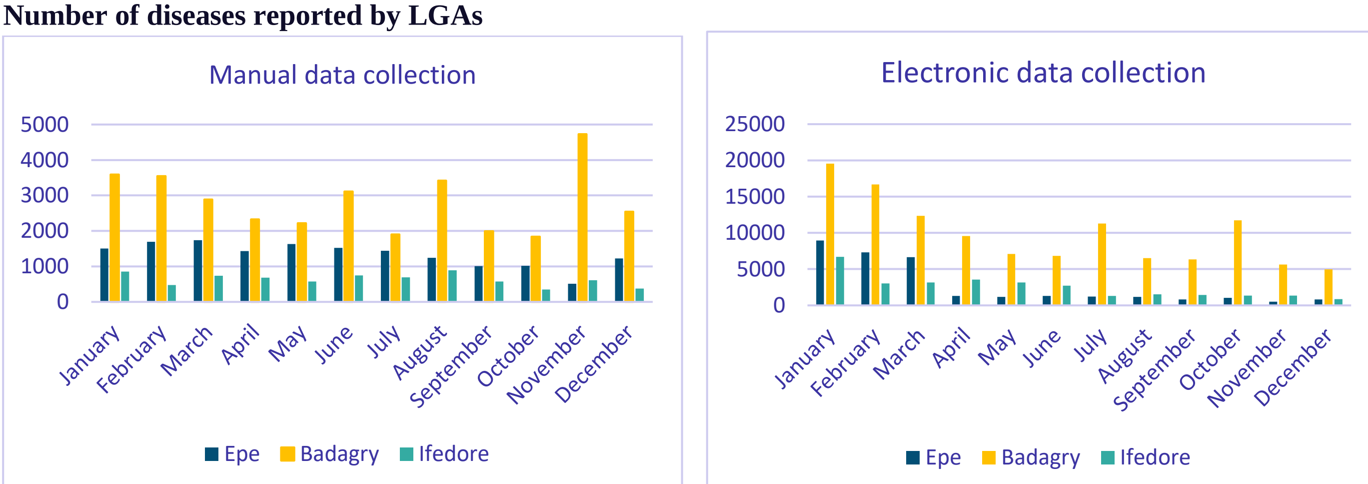
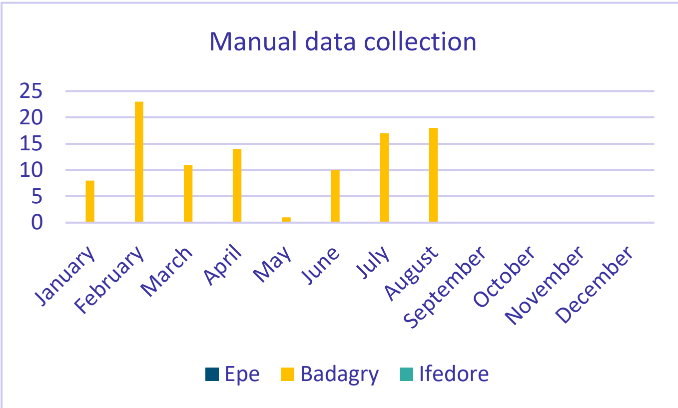


Figure 3: Monthly number of all diseases reported using the manual and electronic data collection methods by LGAs in 2018

Using the manual method of data collection, Badagry LGA reported all the deaths while other LGAs reported no deaths (Figure 4). Using the electronic method, Badagry LGA reported the most deaths followed by Epe LGA. On the other hand, Ifedore LGA did not report any deaths using both methods.

Number of deaths reported by LGAs



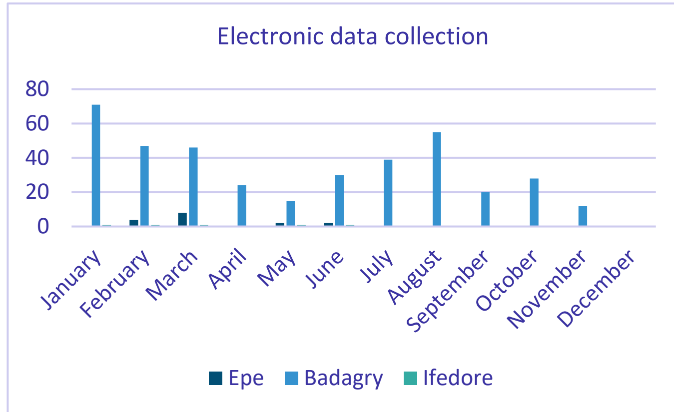


Figure 4: Monthly number of deaths reported using the manual and electronic data collection methods by LGAs

Table 1: Use of the manual and electronic data collection methods to report in-patient cases in the three LGAs

Month	Manual data		Electronic data		Z test value	p-value of difference in proportions
	Total in- and out-patient cases n	In-patient cases n (%)	Total in- and out-patient cases n	In-patient cases n (%)		
January	5937	515 (8.67)	35152	1916 (5.45)	9.738	<0.001
February	5691	447 (7.85)	27016	1499 (5.55)	6.684	<0.001
March	5353	337 (6.30)	22084	1367 (6.19)	0.287	0.774
April	4429	331 (7.47)	14381	1979 (13.76)	-11.148	<0.001
May	4415	249 (5.64)	11420	918 (8.04)	-5.180	<0.001
June	5379	421 (7.83)	10796	902 (8.36)	-1.155	0.248
July	4015	224 (5.58)	13772	1064 (7.73)	-4.618	<0.001
August	5528	397 (7.17)	9153	890 (9.72)	-5.276	<0.001
September	3571	251 (7.03)	8575	528 (6.16)	1.786	0.074
October	3211	193 (6.01)	14087	656 (4.66)	3.205	0.001
November	5850	251 (4.30)	7481	494 (6.60)	-5.769	<0.001
December	4140	465 (11.23)	6638	413 (6.22)	9.249	<0.001
Total cases in the year	57519	4081 (7.10)	180555	12626 (7.00)	0.835	0.404

The manual data collection method reported a statistically significant (p<0.05) higher proportion of in-patient cases in four months of the year (January, February, October and December), while the electronic method reported a statistically significant (p<0.05) higher proportion of in-patient cases in five months of the year (April, May, July August and November). Overall, there was not statistically significant (p=0.404) differences between the two methods in reporting the total in-patient cases in 2018 (Table 1).

Table 2: Use of the manual and electronic data collection methods to report out-patient cases in the three LGAs

Month	Manual data		Electronic data		Z test value	p-value of difference in proportions
	Total in- and out-patient cases n	Out-patient cases n (%)	Total in- and out-patient cases n	Out-patient cases n (%)		
January	5937	5422 (91.33)	35152	33236 (94.55)	-9.738	<0.001
February	5691	5244 (92.15)	27016	25517 (94.45)	-6.683	<0.001
March	5353	5016 (93.71)	22084	20717 (93.81)	-0.287	0.774
April	4429	4098 (92.53)	14381	12402 (86.24)	11.148	<0.001
May	4415	4166 (94.36)	11420	10502 (91.96)	5.180	<0.001
June	5379	4958 (92.17)	10796	9894 (91.65)	1.155	0.248
July	4015	3791 (94.42)	13772	12708 (92.27)	4.618	<0.001
August	5528	5131 (92.82)	9153	8263 (90.28)	5.277	<0.001
September	3571	3320 (92.97)	8575	8047 (93.84)	-1.786	0.074
October	3211	3018 (93.99)	14087	13431 (95.34)	-3.205	0.001
November	5850	5599 (95.71)	7481	6987 (93.40)	5.769	<0.001
December	4140	3675 (64.61)	6638	6225 (93.78)	-38.824	<0.001
Total cases in the year	57519	53438 (92.90)	180555	167929 (93.00)	-0.835	0.404

Table 2 does not need to be reported because the p-values and Z test values are the same as those in Table 1. In other words, Table 2 is a complement of Table 1 because it reports out-patient cases in all the LGAs.

Table 3: Use of the of the manual and electronic data collection methods to report in-patient cases in Badagry LGA

Month	Manual data		Electronic data		Z test value	p-value of difference in proportions
	Total in- and out-patient cases n	In-patient cases n (%)	Total in- and out-patient cases n	In-patient cases n (%)		
January	3582	358 (9.99)	19499	1624 (8.33)	3.271	0.001
February	3518	257 (7.31)	16644	1288 (7.74)	-0.878	0.380
March	2873	161 (5.60)	12298	1094 (8.90)	-5.767	<0.001
April	2310	166 (7.19)	9534	1819 (19.08)	-13.731	<0.001
May	2215	36 (1.63)	7101	735 (10.35)	-13.013	<0.001
June	3103	307 (9.89)	6788	760 (11.20)	-1.938	0.053
July	1882	158 (8.40)	11265	976 (8.66)	-0.384	0.701
August	3397	220 (6.48)	6466	788 (12.19)	-8.897	<0.001
September	1989	126 (6.35)	6313	513 (8.13)	-2.614	0.009
October	1839	106 (5.76)	11716	649 (5.54)	0.390	0.696
November	4728	167 (3.53)	5646	485 (8.59)	-10.572	<0.001
December	2542	319 (12.55)	4970	413 (8.31)	5.862	<0.001
Total cases in the year	33978	2381 (7.01)	118240	11144 (9.43)	-13.803	<0.001

Table 3 shows that the manual method of data collection reported a statistically significant ($p<0.05$) higher proportion of in-patient cases in Badagry LGA twice in the year (January and December), while the electronic method reported a statistically significant ($p<0.05$) higher proportion of in-patient cases in six months of the year (March, April, May, August, September and November). Overall, more total in-patient cases were reported using the electronic method (9.4%) than the manual method (7.0%) in Badagry LGA and this difference was statistically significant ($p<0.001$).

Table 4: Use of the manual and electronic data collection methods to report out-patient cases in Badagry LGA

Month	Manual data		Electronic data		Z test value	p-value of difference in proportions
	Total in- and out-patient cases n	Out-patient cases n (%)	Total in- and out-patient cases n	Out-patient cases n (%)		
January	3582	3224 (90.01)	19499	17875 (91.67)	-3.271	0.001
February	3518	3261 (92.70)	16644	15356 (92.26)	0.878	0.380
March	2873	2712 (94.40)	12298	11204 (91.10)	5.767	<0.001
April	2310	2144 (92.81)	9534	7715 (80.92)	13.731	<0.001
May	2215	2179 (98.38)	7101	6366 (89.65)	13.013	<0.001
June	3103	2796 (90.11)	6788	6028 (88.80)	1.938	0.053
July	1882	1724 (91.61)	11265	10289 (91.34)	0.384	0.701
August	3397	3177 (93.52)	6466	5678 (87.81)	8.897	<0.001
September	1989	1863 (93.67)	6313	5800 (91.87)	2.614	0.009
October	1839	1733 (94.24)	11716	11067 (94.46)	-0.390	0.696
November	4728	4561 (96.47)	5646	5161 (91.41)	10.572	<0.001
December	2542	2223 (87.45)	4970	4557 (91.69)	-5.862	<0.001
Total cases in the year	33978	31597 (92.10)	118240	107096 (90.58)	13.803	<0.001

Table 4 does not need to be reported because the p-values and Z test values are the same as those in Table 3 above. In other words, Table 4 is a complement of Table 3 because it reports out-patient cases in Badagry LGA.

Table 5: Use of the manual and electronic data collection methods to report in-patient cases in Ifedore LGA in 2018

Month	Manual data		Electronic data		Z test value	p-value of difference in proportions
	Total in- and out-patient cases n	In-patient cases n (%)	Total in- and out-patient cases n	In-patient cases n (%)		
January	853	0 (0.00)	6716	134 (2.00)	-4.163	<0.001
February	474	0 (0.00)	3040	33 (1.09)	-2.279	0.023
March	739	0 (0.00)	3163	77 (2.43)	-4.284	<0.001
April	684	0 (0.00)	3548	103 (2.90)	-4.511	<0.001
May	572	16 (2.80)	3151	93 (2.30)	-0.201	0.840
June	751	30 (4.00)	2723	28 (1.03)	5.617	<0.001
July	688	11 (1.60)	1290	8 (0.62)	2.125	0.034
August	887	24 (2.71)	1521	4 (0.26)	5.394	<0.001
September	572	23 (4.02)	1455	14 (0.96)	4.630	<0.001
October	353	0 (0.00)	1330	6 (0.45)	-1.264	0.206
November	612	21 (3.43)	1341	9 (0.67)	4.601	<0.001
December	374	0 (0.00)	867	0 (0.00)	-	-
Total cases in the year	7559	125 (1.65)	30145	509 (1.69)	-0.211	0.833

In Table 5, in Ifedore LGA, the manual data collection method reported a statistically significant ($p<0.05$) higher proportion of in-patient cases in five months of the year (June, July, August, September and November), while the electronic method reported a statistically significant ($p<0.05$) higher proportion of in-patient cases in four months of the year (January, February, March and April). Overall, there was no statistically significant ($p=0.833$) difference between the two methods in reporting the total in-patient cases in 2018 in Ifefore LGA.

Table 6: Use of the manual and electronic data collection methods to report out-patient cases in Ifedore LGA in 2018

Month	Manual data		Electronic data		Z test value	p-value of difference in proportions
	Total in- and out-patient cases n	Out-patient cases n (%)	Total in- and out-patient cases n	Out-patient cases n (%)		
January	853	853 (100.00)	6716	6582 (98.01)	4.163	<0.001
February	474	474 (10.00)	3040	3007 (98.92)	2.279	0.023
March	739	739 (100.00)	3163	3086 (97.54)	4.284	<0.001
April	684	684 (100.00)	3548	3445 (97.10)	4.511	<0.001
May	572	556 (97.20)	3151	3058 (97.05)	0.201	0.840
June	751	721 (96.01)	2723	2695 (98.97)	-5.617	<0.001
July	688	677 (98.40)	1290	1282 (99.38)	-2.125	0.034
August	887	863 (97.29)	1521	1517 (99.74)	-5.394	<0.001
September	572	549 (95.98)	1455	1441 (99.04)	-4.630	<0.001
October	353	353 (100.00)	1330	1324 (99.55)	1.264	0.206
November	612	591 (96.57)	1341	1332 (99.33)	-4.601	<0.001
December	374	374 (100.00)	867	867 (100.00)	-	-
Total cases in the year	7559	7434 (98.35)	30145	29636 (98.31)	0.211	0.833

Table 6 does not need to be reported because the p-values and Z test values are the same as those in Table 5 above. In other words, Table 6 is a complement of Table 5 because it reports out-patient cases in Ifefore LGA.

Table 7: Use of the manual and electronic data collection methods to report in-patient cases in Epe LGA

Month	Manual data		Electronic data		Z test value	p-value of difference in proportions
	Total in- and out-patient cases n	In-patient cases n (%)	Total in- and out-patient cases n	In-patient cases n (%)		
January	1502	157 (10.45)	8937	158 (1.77)	18.205	<0.001
February	1699	190 (11.18)	7332	178 (2.42)	16.447	<0.001
March	1741	176 (10.11)	6623	196 (3.00)	12.877	<0.001
April	1435	165 (11.50)	1299	57 (4.39)	6.797	<0.001
May	1628	197 (12.10)	1168	90 (7.71)	3.777	<0.001
June	1525	84 (5.51)	1285	114 (8.87)	-3.471	0.001
July	1445	55 (3.81)	1217	80 (6.57)	-3.242	0.001
August	1244	153 (12.30)	1166	98 (8.41)	3.128	0.002
September	1010	102 (10.10)	807	1 (0.12)	9.136	<0.001
October	1019	87 (8.54)	1041	1 (0.10)	9.473	<0.001
November	510	63 (12.35)	494	0 (0.00)	8.069	<0.001
December	1224	146 (11.93)	801	0 (0.00)	10.147	<0.001
Total cases in the year	15982	1575 (9.86)	32170	973 (3.03)	31.527	<0.001

Table 7 shows that the manual method of data collection reported a statistically significant ($p<0.05$) higher proportion of in-patient cases in Epe LGA in ten months of the year (January to May and August to December), while the electronic method reported a statistically significant ($p<0.05$) higher proportion of in-patient cases twice in the year (June and July). Overall, more total in-patient cases were reported using the manual method (9.9%) than the electronic method (3.0%) in Epe LGA and this difference was statistically significant ($p<0.001$).

Table 8: Use of the manual and electronic data collection methods to report out-patient cases in Epe LGA

Month	Manual data		Electronic data		Z test value	p-value of difference in proportions
	Total in- and out-patient cases n	Out-patient cases n (%)	Total in- and out-patient cases n	Out-patient cases n (%)		
January	1502	1345 (89.55)	8937	8779 (98.23)	-18.205	<0.001
February	1699	1509 (88.82)	7332	7154 (97.57)	-16.447	<0.001
March	1741	1565 (89.89)	6623	6427 (97.04)	-12.877	<0.001
April	1435	1270 (88.50)	1299	1242 (95.61)	-6.797	<0.001
May	1628	1431 (87.90)	1168	1078 (92.30)	-3.777	<0.001
June	1525	1441 (94.49)	1285	1171 (91.13)	3.471	0.001
July	1445	1390 (96.19)	1217	1137 (93.43)	3.242	0.001
August	1244	1091 (87.70)	1166	1068 (91.60)	-3.128	0.002
September	1010	908 (89.90)	807	806 (99.88)	-9.136	<0.001
October	1019	932 (91.46)	1041	1040 (99.90)	-9.473	<0.001
November	510	447 (87.65)	494	494 (100.00)	-8.069	<0.001
December	1224	1078 (88.07)	801	801 (100.00)	-10.147	<0.001
Total cases in the year	15982	14407 (90.15)	32170	31197 (96.98)	31.527	<0.001

Table 8 does not need to be reported because the p-values and Z test values are the same as those in Table 7 above. In other words, Table 8 is a complement of Table 7 because it reports out-patient cases in Epe LGA.

Completeness Analysis

Study Setting

This study was conducted in all the functional health facilities in the study LGA between January and December 2018. Badagry had 57 functional public and private health facilities 21 Primary Health Centers (PHCs), 35 private hospitals and 1 General hospital. Epe has 25 functional health facilities, 2 General hospitals, 4 private hospitals and 19 PHCs. Ifedore has 28 health facilities, 1 general hospital and 27 PHCs.

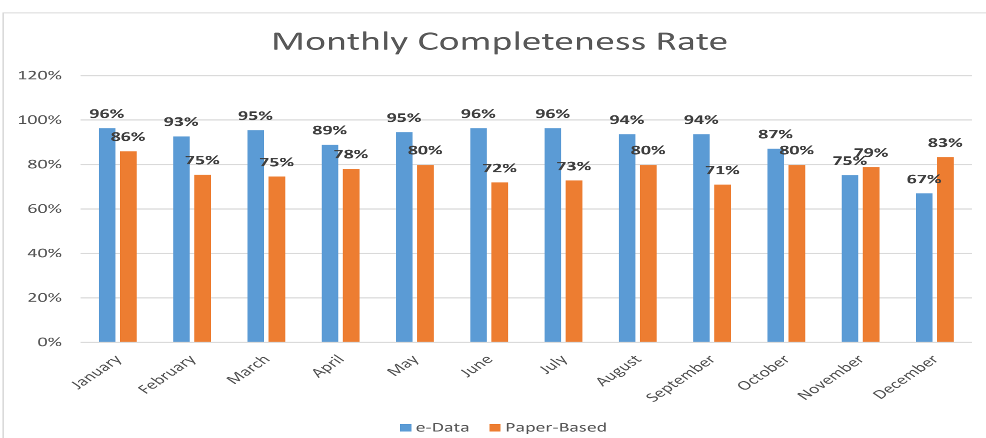
State	LGA	No of facilities
Lagos	Badagry	57
	Epe	25
Ondo	Ifedore	28
		110

Results

Completeness of data was measured by the coverage count of the number of facilities that reported on the IDSR 003 forms across the 3 LGAs monthly. The table below shows the percentage of completeness in 2018. November and December represent outliers in this analysis with paper-based reporting higher than e-data. Supervisors required that paper forms be completed and submitted by facilities to comply with this part of their annual performance evaluation. This resulted in facility workers focusing more on paper completion and submission, later in the year, at the expense of e-data especially, as EDC was only being piloted and not accepted in place of Paper.

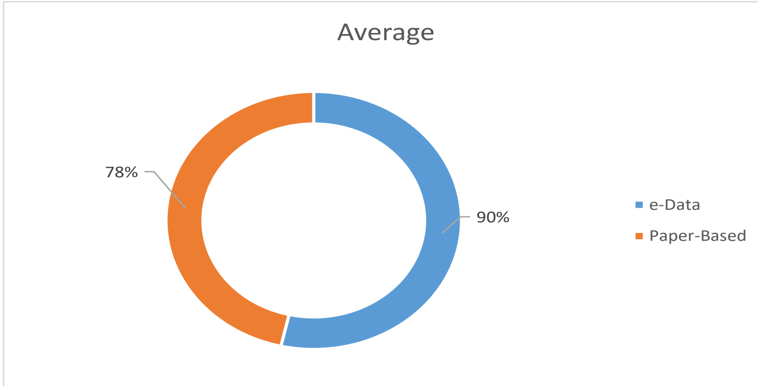
	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
e-data (%)	96.3	92.6	95.4	88.9	94.5	96.3	96.3	93.6	93.6	87.1	75.2	67.0
Paper-based (%)	85.9	75.4	74.6	78.1	79.8	71.9	72.8	79.8	71.0	79.8	78.2	83.3

Table showing comparison between e-data and paper-based completeness



The above figure shows higher completeness rates for e-data across the year except for the month of November and December.

Average Monthly Completeness Rate



The total average completeness rate for e-data surveillance is 90% while paper-based surveillance is 78% showing 12% incremental data completeness associated with electronic surveillance.

Discussion

The completeness of electronic based surveillance is superior to the paper-based method. This study shows the introduction of the electronic surveillance to the disease surveillance and notification system results in a 12% higher in data completeness. A major feature of the electronic data capture that encourages data entry clerks to report more data using electronic methods is the effectiveness is ease use and the ability to review data in real time. Henry et al., 2012, also demonstrated that a smartphone data collection system was more likely to be complete, have fewer inconsistencies and outperform paper systems for influenza sentinel surveillance in Kenya. There was a higher incidence of incomplete records in the paper data than in the smartphone data adjusted to incidence rate ratio. Similarly, our quantitative results on data completeness are consistent with findings from Estelle et al., 2017 study which proved that interviews carried out using electronic data capture had a lower proportion of missing data, and a level of internal validity, compared to those collected on paper.

Accuracy Analysis

Electronic data capture systems are become important tools for endeavors that require high levels of data accuracy including academic, medical device, biotech, and pharmaceutical research. Paper captured data involves data capture with case report forms, which are sometimes subsequently entered into a database to create electronic records. This method is time-consuming and error prone.

Thriemer, K., Ley, B., Ame, S.M. et al carried out a comparative study on paper data capture and Patient Digital Assistant (PDA) based data collection during a fever surveillance study in Pemba Island, Zanzibar, Tanzania. Data were collected on a 14-page case report paper form in the first period of the study. The Case Report Paper Forms (CRF) were then replaced with handheld computers (personal digital assistants or PDAs). The PDAs were used for screening and clinical data collection, including a rapid assessment of patient eligibility, real time errors, and inconsistency checking. The comparison of paper-based data collection with PDA data collection showed that direct data entry via PDA was significantly faster and 25% cheaper. Data was more accurate (7% versus 1% erroneous data respectively) and omission did not occur with electronic data collection. According to their report, a total of 180 patients were enrolled using paper-based data collection, and 2,209 patients were registered and enrolled using PDAs. The use of paper CRFs was compared with direct data entry using PDAs in regard to implementation, outcome, and costs.

Omissions and accuracy for paper-based versus PDA based data collection

Replacing paper data collection forms with electronic data entry in the field: findings from a study of community-acquired bloodstream infections in Pemba, Zanzibar

	Paper			PDA			P
	Number of variables checked	Number of records	Number (%) of omission	Number of variables checked	Number of records	Number (%) of omission	
Omissions	32	180	342 (6%)	5	2209	0 (0%	< 0.05
Accuracy	5	180	65 (7%)	5	2209	95 (1%)	< 0.05

David G.D, Fraser P, Stephen R, et al postulated that the advantage of the Electronic Questionnaire (EQ) is its increased data collection accuracy and this is based on the study of the African Partnership for Chronic Disease Research (APCDR) who developed an open-source electronic questionnaire (EQ) to help facilitate large-scale multicenter studies in sub-Saharan Africa. This validation study compares the APCDR EQ with traditional pen-and-paper methods to assess the relative efficiency and accuracy of the EQ. The study compared the EQ against traditional pen-and-paper methods using 200 randomized interviews conducted in an ongoing type 2 diabetes case–control study in South Africa. The study showed that EQ had a lower number of major errors per 100 questions (EQ, 0.00 errors; paper, 0.59 errors; $P < 0.001$), as well as a lower overall number of errors per 100 questions (EQ, 0.17 errors; paper, 0.73 errors; $P < 0.001$). When using the pen-and-paper method, at least one error occurred every three interviews on average (33.4% of interviews contained at least one error), whereas for the EQ an error occurred once every 14 interviews on average (7.6% of interviews contained at least one error).

A study carried out by Walther B, Hossin S, Townend J, Abernethy N, et al compared four EDC methods with the conventional approach with respect to duration of data capture and accuracy. This paper compared the performance of four electronic data capture methods: PDA, Netbook, Tablet PC and EDC during a telephone interview via mobile phone with the performance of conventional paper-based data collection in a Gambian medical research field station setting. Over a study period of three weeks the error rates decreased considerably for all EDC methods. In the last week of the study the data accuracy for the netbook (5.1%, CI95%: 3.5–7.2%) and the tablet PC (5.2%, CI95%: 3.7– 7.4%) was not significantly different from the accuracy of the conventional paper-based method (3.6%, CI95%: 2.2–5.5%), but error rates for the PDA (7.9%, CI95%: 6.0–10.5%) and telephone (6.3%, CI95% 4.6–8.6%) remained significantly higher. While EDC interviews take slightly longer, data became readily available after download, making EDC more time effective.

Table 2. Error rate (%) per week - Trend over time.

Method	1st week		2nd week		3rd week		3rd week compared to 1st week	Trend over time
	Mean	CI95%*	Mean	CI95%*	Mean	CI95%*	p**	$p_{adjusted}$***
Paper	5.2	3.4–7.1	4.3	2.6–6.0	3.6	2.0–5.2	0.189	0.210
Netbook	8.8	6.5–11.2	5.9	4.0–7.9	5.0	3.2–6.9	0.013	0.012
Tablet	6.3[#]	3.7–8.9	4.9	3.1–6.7	5.2	3.4–7.1	0.499	0.642
PDA	13.2[✧]	10.3–16.0	6.7	4.6–8.7	7.9	5.7–10.2	0.005	0.003
Telephone	10.5	7.9–13.0	9.9	7.4–12.4	6.3	4.3–8.3	0.013	0.014

*Wilson 95% confidence interval for the error rate.
#Error rate(%) for three interviews using the tablet.
✧Error rate(%) for four interviews using the PDA.
**p-value for the test of proportions comparing the error rates for the first and third week of the study.
***p-value, mixed effect model adjusting for the clustering effects for 'fieldworker' and 'order' in which the interviews were conducted.
doi:10.1371/journal.pone.0025348.t002

Electronic Surveillance: Outbreak Policy and Mitigation Planning Imperatives

Our Qualitative and Quantitative analyses comparing Electronic and Paper reporting methods arrive at the same conclusion: Electronic Data Collection and management is a superior method of data management for disease surveillance and reporting in LMICs. In this section of the report we will present the implications of Electronic Data Management and Surveillance on Outbreak Policy and Management in LMICs.

Priorities for Strengthening IDSR

As proxy for improved Disease Surveillance Reporting and Outbreak response we will first examine capacity for Electronic Surveillance regimes to delivery on the priorities for strengthening IDSR. According to the WHO, the priorities for strengthening IDSR are as follows:

- Improve IDSR Core Indicators (Please see Appendix 3 for the WHO Core IDSR Indicators)
    - Timely and complete reporting (tools, guidelines, and case definitions)
    - Timely outbreak detection and response
    - Log of suspected outbreaks and rumors
    - Regular feedback
- Build capacity of Surveillance personnel (SE, DSNOs, FPs)
    - Optimize monthly review meetings
    - Joint supervision and review of surveillance performance
    - Prioritization of supportive supervision
    - Data analysis and Use for data for action
    - Outbreak investigation, reporting and response
- Improve documentation
    - State and LGA levels e.g. activities, meetings, supervision, etc.

The Electronic Data sets analyzed against paper-based records in this research were electronic forms of Nigeria's IDSR Forms (001, 002 and 003). Therefore, the availability of timely, accurate and relatively complete electronic data sets in the three study LGAs demonstrate the capacity of electronic surveillance to deliver on the following priorities for strengthening IDSR directly:

- Improve IDSR core indicators
    - Timely and complete reporting (tools, guidelines, and case definitions)
    - Timely outbreak detection and response
    - Log of suspected outbreaks and rumours
    - Regular feedback
- Build capacity of Surveillance personnel
    - Data analysis and Use for data for action

Electronic surveillance provides the mechanisms through which the following priorities of strengthening IDSR can be addressed:

- Build capacity of Surveillance personnel
    - Optimize monthly review meetings

- Joint supervision and review of surveillance performance
- Outbreak investigation, reporting and response

Syndromic Surveillance

Early detection of outbreaks is a significant factor in controlling outbreaks. According to an excerpt from the WHO Key Facts About Major Deadly Diseases (V1, PartI, Page 18), "Recent outbreaks, however, show how difficult this can be, even with good public health surveillance systems. Early recognition of emergence typically starts with clinicians who can detect unusual clusters of severe cases, take samples to allow laboratory diagnostics and alert surveillance units".

Syndromic surveillance has been established by the literature as the most practical surveillance approach in low resource settings. Syndromic Surveillance uses pre-diagnostic data and statistical algorithms to detect epidemics which may include unusual diseases with non-specific presentations. Syndromic surveillance tools are ideal for implementation in resource-limited settings given the inherently weak healthcare and laboratory systems. There are very few laboratories in rural areas given that most labs are concentrated in the urban centers. The few available in the rural areas, and even most in urban areas, are basic labs that are not capable of carrying out advanced testing. During the 2015 incident of acute methanol poisoning in Ondo State tissue samples were sent hundreds of kilometers away to the National Hospital Abuja and to the University College Hospital Ibadan for toxicology studies. Such infrastructure levels are grossly inadequate for effective and timely outbreak response. It is important therefore that this lag-time caused by the need for laboratory testing and diagnoses is reduced by surveillance of pre-diagnostic syndromes of these diseases, serving as an early warning of impeding disease outbreaks and these are communicated through the disease surveillance community to alert of possible outbreaks in a more timely manner. Syndromic Surveillance also supports public health "situational awareness" by facilitating the monitoring of the effectiveness of epidemic responses as well as by characterizing affected populations.

Predictive Analytics

Predictive analytics is a broad term describing a variety of statistical and analytical techniques used to develop models that predicts future events or behaviors. The form of these predictive models varies, depending on the behavior or event that they are predicting. Predictive analytics encompasses a variety of statistical techniques from data mining, predictive modelling, and machine learning, that analyze current and historical facts to make predictions about future or otherwise unknown events.

Predictive analytics along with most predictive models and data mining techniques rely on increasingly sophisticated statistical methods including multivariate analysis techniques such as advanced regression or time-series model. Such techniques enable organizations to determine trends and relationships that may not be readily apparent, but still enable it to better predict future events or behaviors.

The use of climate data for predicting outbreaks of infectious diseases dates to work by Gill and others in India. Gill (1923) developed an EWS for malaria based on rainfall, prevalence of enlarged spleens, economic conditions (price of food grains) and epidemic potential (the coefficient of variation of fever mortality during October for the period 1828-1921). Iwayemi Akin et al noted that Nigeria and the rest of Sub-Saharan Africa (SSA) are yet to effectively join the rest of the world in making extensive use of this important decision-making tool. Yet, the conditions for their use exist with the increasingly large amount of administrative, health, economic, financial, social, and technical data set generated by government's offices, business enterprises and households.

Malaria, as one of the most serious infectious diseases causing public health problems in the Africa, affects about two-thirds of the world population, with estimated resultant deaths close to a million annually. In view of this, Modu, Babagana & Polovina, Nereida et al carried out a study which aimed to design and deploy an intelligent malaria outbreak early warning system, which is a mobile application that predicts malaria outbreak based on climatic factors using machine learning algorithms. The system will help hospitals, healthcare providers, and health organizations take precautions in time and utilize their resources in case of emergency. This study also makes a significant contribution by identifying hidden ecological factors of malaria (e.g., temperature, humidity, wind, location, drought, floods, etc.).

Disease Outbreak Mitigation Planning

The development of suitable pandemic mitigation strategies is a challenging task, which must consider numerous epidemiological, sociological, logistical, and operational factors. Since the devastation from a pandemic could occur very rapidly (perhaps, in a few weeks), it is essential that scalable mitigation strategies supported by comprehensive and scientifically valid models are developed beforehand and made available to the healthcare delivery decision makers. Such strategies could also serve as valuable tools for healthcare personnel training and preparedness exercises.

Strengths and Challenges of Newly Emerging Surveillance Systems

Internet-based systems are intuitive, adaptable, and inexpensive to maintain, and operate in real time. Advanced computational capabilities enable automated and rapid collection of large volumes of data, referred to as “big data”, and provide the public with “real-time” detection and improved early notification of localized outbreaks. In addition, a system based on web queries can easily be applied to various infectious diseases, as the underlying mechanisms could be similar.

However, internet-based surveillance systems have been met with some skepticism. Due to the unstructured nature of the data sources, interpreting the information may require overly complex techniques to effectively implement the system initially. A powerful cited case study is the Google Flu Trend (GFT) proposition through which, in 2008, researchers from Google claimed that they could “nowcast” the flu based on people’s searches. Unfortunately, GFT missed the peak of the 2013 flu season by 140 percent and was subsequently shut down by Google. Data sharing permits more and better-quality data to be used to monitor public health and potential outbreaks. However, use of data with precise information connected to individuals raise privacy concerns. Careful and appropriate decisions need to be made to avoid any further privacy intrusion on personal information.

Although monitoring trends in disease outbreaks and health outcomes is possible, forecasting them is susceptible to false positives or false negatives. Thus, data sources must be evaluated extensively, particularly to identify gaps in coverage and false decisions. Challenges with data integration, compatibility, and evaluating surveillance systems will likely remain well into the future. As such continued evolution backed by more research will be necessary.

Electronic Disease Surveillance in LMICs: Policy Options

The increased availability of data afforded by EDC systems will improve the capacity of LMICs to prepare for and mange outbreaks if they occur. EDCs which include electronic surveillance can help LMICs to improve integrated disease surveillance and response core indicators, including timely and complete reporting; timely outbreak detection and response; building capacity of surveillance personnel and the use of data for action. If LMICs successfully introduce and scale EDCs and electronic surveillance, critical imperatives such the use of syndromic surveillance for early disease outbreak detection and predictive analytical models and algorithms for outbreak prediction which in turn will inform disease outbreak prevention strategies.

ICTs have become ubiquitous across all aspects human endeavor including business, governance, education, and commerce; just to name a few. ICT has also played a critical role in improving health care for individuals and communities by enabling new and more efficient ways of accessing, communicating, and storing information. LMICs must adopt ICT frameworks and platforms to effectively position themselves to fully take advantage of the potential that EDC and electronic surveillance systems present for proactive disease surveillance and response. Technologies that present the unifying ecosystem include the following:

- Electronic Medical Records Systems that have been adopted at hospitals and now increasingly in primary health care facilities
- Supply Chain Management Systems
- Disease Surveillance and Response
- Health Worker Training
- Human Resource Management
- Telemedicine/Telehealth
- Health Insurance Management
- Treatment Adherence/Appointment Reminders

Adoption of the above technologies will provide multiple benefits to countries that adopt them. The most immediate benefits relate to the core health systems strengthening imperative of outbreak mitigation. ICT technologies that are currently deployed in the region will help accomplish the use of syndromic surveillance for early outbreak warning; outbreak prediction using big data and artificial intelligence principles; inform vector control activities and build health worker capacity to detect, control and manage diseases and outbreaks.

Outbreak Mitigation

Disease outbreak mitigation planning through the development of scalable mitigation strategies could also serve as valuable tools for healthcare personnel training and preparedness exercises. The most cost-effective strategies for increasing outbreak preparedness, especially in resource-constrained settings of LMICs include investments to strengthen core public health infrastructure, including water and sanitation systems; increasing situational awareness; and rapidly extinguishing sparks that could lead to pandemics. Outbreak mitigation strategies which ICT adoption will inform and strengthen include:

Strengthening Health Systems: To mitigate the impact of epidemics, protect the health workforce and ensure continuity of health services during and after them, stronger health systems are needed. Epidemics and pandemics put these systems under great pressure and stress. The sudden influx of large numbers of sick individuals to health facilities stretches the systems' capacity and resources, even more so and more noticeably where resources are

already scarce. Furthermore, health care settings, and especially emergency rooms, can become hubs of transmission. Many people get infected there if prevention and control measures are not properly implemented.
A delay in the recognition of the disease will lead to delay in applying the right protection measures. In countries where there are health staff shortages, the loss of several more health workers further weaken the health system. It takes years to train new medical staff and rebuild the health workforce if significant numbers of the health workforce are lost from exposure to epidemics. Long-term substantial investments should therefore be made to strengthen health systems, so they are able to provide safe, effective, and qualitative health services before, during and after epidemics. Critical elements include the following:

- An appropriate health financing system
- A fit-for-purpose workforce that is trained, safe and provided with personal protective equipment
- Access to essential medical products and technologies
- Business continuity plans to ensure that health systems are strong enough to withstand the increased needs and to mitigate the impacts of outbreaks.

Prevention of Vector-Borne Diseases (VBD): To prevent the transmission of VBDs, actions can be taken to protect human beings from the vectors and/or to eliminate or reduce vectors population. These actions include vector control, community engagement, and personal protection. Vector Control Activities are deployed at the community level to eliminate the vectors and larvae as much as possible, to prevent or control the transmission of VBDs. The operationalization of vector control varies according to the type of vector and transmission intensity. Mosquito surveillance is part of vector control and helps improve timeliness of decisions to control mosquito populations and prevention disease. Both larval and adult vector populations should be targeted for surveillance. Epidemiological and entomological surveillance/indicators should be collected and analyzed in close collaboration.

Other vector control activities include:

- *Environmental measures* through sanitation, habitat management and livestock management.
- *Mechanical measures* with trapping of vectors.
- *Biological tools* using natural enemies and biological larvicides for mosquitoes.
- *Other chemicals* such as the use of mimics of natural hormones to stop the insect development.

A new generation of vector control products is also arriving with genetically modified organisms. For example, The State of Florida announced in August 2020, a program to release of genetically modified mosquitoes as part of its vector control program. The success of the new program still has not been evaluated yet and as such cannot yet be recommended as an effective vector control method.

Community Engagement also an important component for controlling VBDs. Through participative actions, such as recommendations for personal protection in the working places and schools, elimination of breeding sites, installation of window screens, and overall surveillance of the environment to make it less favorable for mosquitoes, are some of the major actions that can be taken by communities.

Nigeria has arguably transitioned from experimentation and early adoption phases of health ICT, to increasingly scaled implementation of ICT projects. The private sector has played an important role in this transition through entrepreneurial initiatives and Public, Private Partnerships which have resulted in the use of ICT across the spectrum of healthcare delivery services. NCDC used an electronic active case management SORMAS since 2017 and has recently extended and SORMAS open to all priority health facilities in all Nigeria's LGAs. This as well as other private sector led initiatives including the Nigeria Tuberculosis and Leprosy Foundation use of real time electronic data capture systems for tuberculosis surveillance present important examples of scalable electronic data regimes that allow for more accurate, timely, and complete data for health policy and strategy, especially to manage disease outbreaks.

Nigeria has arguably transitioned from experimentation and early adoption phases of health ICT, to increasingly scaled implementation of ICT projects. The private sector has played an important role in this transition through entrepreneurial initiatives and Public, Private Partnerships which have resulted in the use of ICT across the spectrum of healthcare delivery services. Specific ICTs for adoption include the following:

- Electronic Medical Records Systems that have been adopted at hospitals and now increasingly in primary health care facilities (e.g. Helium Health, InStrat)
- Supply Chain Management (e.g. LMIS, Spoxil)
- Disease Surveillance and Response (e.g. SORMAS, EWORS, MSERS)
- Health Worker Training (e.g. VTR Mobile)
- Human Resource Management (e.g. HRIS)
- Telemedicine/Telehealth (e.g. MobiHealth, MDoc)
- Health Insurance Management (e.g. Care Pay, InStrat); Treatment Adherence/Appointment Reminders (e.g. txtalert).

Adoption of the above technologies will provide multiple benefits to countries that adopt them. The most immediate benefits relate to the Core Health systems strengthening imperative of Outbreak Mitigation. ICT technologies that are currently deployed in the region will help accomplish the following:

- Use of Syndromic Surveillance for early outbreak warning
- Outbreak prediction using Big Data and Artificial Intelligence principle
- Inform vector control activities
- Build health worker capacity to detect, control and manage diseases and outbreaks

Conclusion

All research conducted including the Quantitative, Qualitative, Completeness and Accuracy Analyses yielded conclusions that electronic health data management was a superior system of data collection and management for disease surveillance and response and health policy more generally. Electronic data regimes will provide frameworks through which Governments can improve Integrated Disease Surveillance and Response core indicators using electronic surveillance. As such adopting ICT technologies and platforms will help governments to adopt a more proactive footing as it relates to disease surveillance and response management. ICT will support efforts to strengthen health systems, prevent vector borne and other infectious diseases, improve health outcomes and save lives. These platforms and strategies will help LMICs that adopt them to better comply with the SDG 3: Good Health and Wellbeing.

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Appendix 1: Lessons Learnt Report

Overview

InStrat Global Health Solutions is pleased to submit a Lessons Learned Report as part of the final deliverables under the Innovations Award for the Retrospective Analysis of Electronic Vs. Manual Health Data and Disease Surveillance Records for Implications of Outbreak Management in LMICs, using Nigeria as a Case Study. This Lessons Learned Report address major risks and challenges that InStrat encountered during the research project and the steps taken to mitigate them. This report also includes answers to the Output Indicator Questions as required by the Guidelines for Final Reports and Lessons Learned. This report is included in the main project report as an Appendix.

Risks/Mitigation

The major risk that InStrat encountered in the conduct of this project is the outbreak of the Corona Virus Pandemic and the attendant business closures and social distancing requirements.

Fortunately, we were required to present a Contingency Plan prior to the initiation of this project. The plan contained actions that we met the Project's deliverables without violating local or international COVID-19 Management Guidelines or endangering the health and wellbeing of any of our staff, partners, or stakeholders. To mitigate the risks posed by the COVID 19 Pandemic, we meticulously followed the plan and instituted human resources measures to ensure staff compliance. The key elements of the risks and mitigation steps taken are presented in the tablet below:

Function	Platform	Actions
Communications	Telephone	This was the predominant mode of communication allowing us to coordinate amongst our team, set up research interviews and coordinate field data gathering activities.
	Telephone conference Lines	We made extensive use our 'Free Conference' facility to hold voice calls that involved multiple people in areas where there was poor internet connectivity. This was heavily used in field data canvassing in Ondo State.
	Email	Official communication between InStrat team as well as with external parties that supported the various research efforts for the project.
	WhatsApp	Coordination and alignment communication requiring rapid response and feedback.
	Zoom/Skype	This was extensively used for meetings that required real time screen sharing.

Desk Research	Internet	The desk research was conducted online using the internet to access google, State Government websites and resources, Local libraries, and research websites.
Analytics and collaboration	Google Shared Platforms	Project analytics and collaboration to write the final report were conducted using Google Shared platforms including Google Sheets and Google Docs.
Database	AWS	All data acquired for this purpose was stored on secure cloud servers with access provided to analysts.

Our diligent use of the above platforms facilitated effective collaboration within the InStrat team internally, and with research counterparts externally allowing us to perform all functions in a virtual environment and delivering the project on time without compromising the quality of the research project.

Responses to Output Indicator Questions:

1. Have there been any final results or outcomes in which data or methods have allowed data to be produced: faster; more cheaply; at a higher resolution or granularity, or where there was no data before? If yes, please describe.

   As a research project this project did not directly produce any data that can be used faster; more cheaply; at a higher resolution or granularity, or where there was no data before. However, this research identified policy imperatives and options for adopting Information and Communications Technologies (ICT) to accomplish identified goal though data that is produced faster, more cheaply, more completely, and more accurate and better linked to outcomes.

2. Has the project contributed to the production and/or use of data disaggregated by a) sex b) disability c) age, d) geography (or other)? If yes, please summarize the of types of disaggregation and the context.

   As a research project this project did not produce any data that can directly contribute to the production and/or use of data disaggregated by a) sex b) disability c) age, d) geography (or other). However, the research identified policy options for ICT adoption that will lead to the production of such data.

3. Has the project contributed to the use and/or production of gender statistics? If yes, please describe.

   As a research project this project has not contributed directly to the use and/or production of gender statistics. However, the ICT platforms recommended for adoption will allow the use and/or production of gender statistics.

Lessons Learned

- Technical
  - The requirement to produce a Corona Virus contingent plan provided InStrat a roadmap for navigating the project during the pandemic. We recommend that all projects be required to develop risk mitigation plans.
  - Clearly defined project planning including project objectives, timelines and research frameworks and especially, constraints on uses of the funding helped InStrat to execute the project within the guidelines specified.

- Organizational
  - The project had a clear and effective governance framework with project roles, communications channels, and protocols between the World Bank team and InStrat team.
  - InStrat's selection of Project collaborators that had deep expertise in their selected roles and a track record of performance allowed effective adherence to sub deliverables, the Corona Virus restrictions notwithstanding.

- Potential for Replicability and Scalability
  - This research project did not develop any specific technologies or prototypes that could be replicable or scalable. However, the technologies identified for possible adoption to address opportunities identified in the research are all replicable across all areas of Public health in LMICs and highly scalable within individual countries.

Conclusions

All research conducted including the Quantitative, Qualitative, Completeness and Accuracy Analyses yielded conclusions that electronic health data management was a superior system of data collection and management for disease surveillance and response and health policy more generally. Electronic data regimes will provide frameworks through which Governments can improve Integrated Disease Surveillance and Response core indicators using electronic surveillance. As such adopting ICT technologies and platforms including Electronic Medical Records Systems, Disease Surveillance and Response systems, electronic Health Worker Training and Telemedicine/Telehealth platform will help governments to adopt a more proactive footing as it relates to disease surveillance and response management. ICT will support efforts to strengthen health systems, prevent vector borne and other infectious diseases, improve health outcomes and save lives. These platforms and strategies will help LMICs that adopt them to better comply with the SDG 3: Good Health and Wellbeing.

Appendix 2: Qualitative Interview Guide

State Epidemiologist/Policy Makers

Information area	Example questions and probes	*Comments*
Introduction by respondent		
Section A: *Respondent Functional Context*	State/LGA	
	Functional Title	
	Number years in this position	
	What are your responsibilities in the disease surveillance and response process?	
	What is the predominant mode of data collection for disease surveillance and response in your State?	
Section B: *Electronic data management*	What is your experience with electronic data management processes in your State along the following dimensions?	
	Timeliness	
	Completeness	
	Accuracy	
	How has electronic data management helped with disease surveillance and response within your state?	
	How has electronic data management improved your capabilities in disease surveillance and response in your state?	
	How efficient is electronic data management when compared to Paper collection of IDSR data? (Probe for value for money and timeliness)	
	Would you recommend that electronic data management be extended to all Health facilities and Local Government in the state	
Section B: *Manual/paper-based data management*	What is your experience with Paper based management processes in your State along the following dimensions?	
	Timeliness	
	Completeness	
	Accuracy	
	Please describe the IDSR capture to submission process	
	How often do you receive IDSR Forms?	
	In what formats do you receive the submissions?	
	Are you provided with tools to analyse paper-based reports submissions?	
	What are the challenges that you have encountered with the Paper based processes?	
	Would you recommend that the Paper based processes be continued in all facilities in your LGA?	

Local Government Area DSNOs / Health Facility In-Charges

Information area	Example questions and probes	*Comments*
Introduction by respondent		
Section A: *Respondent Functional Context*	State/LGA	
	Functional Title	
	Number years in this position	
	What are your responsibilities in disease surveillance and response?	
Section B: *Electronic data management*	What is the predominant mode of data collection for disease surveillance and response in your State?	
	What is your experience with electronic data management processes in your State along the following dimensions?	
	Timeliness	
	Completeness	
	Accuracy	
	How has electronic data management helped with disease surveillance and response within your state?	
	How has electronic data management improved your capabilities in disease surveillance and response in your state?	
	What type of feedback do you receive from your supervisors and how often do you receive them? (please probe for types of feedback received from State Epidemiologists)	
	How has electronic data management helped you with Data interpretation and response to disease outbreaks?	
	How efficient is electronic data management when compared to Paper collection of IDSR data? (Probe for value for money and timeliness)?	
	Would you recommend that that electronic data management be extended to all Health facilities and Local Government in the state?	
	What are your challenges with electronic data management?	
	What recommendations would you make for improvement of electronic data management?	
Section B: *Manual/paper-based data management*	Please describe the manual/paper-based management process	
	What is your experience with paper management processes in your State along the following dimensions?	
	Timeliness	
	Completeness	
	Accuracy	
	Please describe the IDSR capture to submission process?	
	How often do you complete IDSR Forms?	
	How long does it typically take to complete an IDSR form?	
	Where are the paper forms submitted?	
	Who is responsible for the cost of transportation to submit paper forms?	

Appendix 3: Quantitative Survey for State Officials

1. Highest Qualification
2. State
   - Lagos
   - Ondo

3. Local Government Area
   - Badagry
   - Epe
   - Ifedore

4. Facility
   Text
5. Title
   - Disease Surveillance Notification Officer
   - State Epidemiologist
   - Community Health Extension Worker
   - Facility In-Charge

6. On a scale of 1 (Has not helped me at all) to 7 (Has Been extremely helpful), please rate how Electronic Data Management helps you improve data interpretation and response to disease outbreaks
7. Electronic Data Management has helped you?
   - Report data in a timely manner
   - Respond to infectious diseases in a timely manner
   - Report data completely
   - Respond to infectious diseases effectively
   - Build your capacity in disease surveillance and response
   - Other (please specify)

8. What do you like about Electronic Data Management?
   - Provide trend analysis for infectious diseases
   - Provides for reliable data
   - Provides for real-time data relay
   - Provide for early recognition of possible outbreaks
   - Provides for rational interpretation of data into meaningful presentations
   - Other (please specify)

9. Rate use of Electronic Data Management tablet from 1 to 5
   1 - Very Poor
   2 - Poor
   3 - Fair

4 - Good
5 - Excellent

- Ease of use tablet
- Network connectivity
- Understanding of Terms used in the tablet
- Training
- Feedback (Following complaints with use of tablet)

10. Would you recommend Electronic Data Management to other health workers not currently using it?

- Yes
- No
- Maybe

14. How much of an impact do you feel Electronic Data Management has had on your work?

- A great deal of impact
- A lot of impact
- A moderate amount of impact

15. What are the challenges you face using Electronic Data Management?

- Training received before Electronic Data Management commenced was inadequate
- Inability to take the tablets home
- Poor internet connectivity at the health facility / Office
- Inadequate feedback from supervisors
- Tablet Freezes (Temporarily stops working)
- Other (please specify)

16. How satisfied are you with your work with the use of Electronic Data Management?

- Very Satisfied
- moderately Satisfied
- Neutral

17. How do you think Electronic Data Management can be improved to be more efficient?
Text

Appendix 4: WHO IDSR Core Indicators

Indicator	Target	Calculation
Proportion of suspected outbreaks of epidemic prone disease notified to the national level within 2 days of surpassing the epidemic threshold	Target 80% Monthly	Number of suspected outbreaks of epidemic prone diseases notified to the national level within 2 days of surpassing the epidemic Threshold in a given time period ÷ Total Number of suspected outbreaks of epidemic prone diseases in the same time period * 100
Proportion of LGAs in which a current line graph is available for selected priority diseases	Target 80% Monthly	Number of LGAs with a Current line graph in a Given time period. ÷ Number of LGAs * 100
Proportion of reports of investigated outbreaks that includes analyzed case-based data	Target 80% Monthly	Number of outbreak investigation reports that Include EPI curve, mapping, Personal Tables and case-based forms or line lists in a given time period ÷ Number of outbreaks Investigation reports in the same time period * 100
Proportion of health facilities submitting surveillance reports on time to the LGA	Target 80% Monthly	Number of health Facilities Submitting reports on time to the LGAs in a Given time period ÷ Total number of Health facilities that should report to the LGAs *100
Proportion of LGAs submitting weekly or monthly surveillance reports on time to the State level	Target 80% Monthly	Number of LGAs that submitted IDSR reports on time to the State level in a given time period ÷ Total Number of LGAs that should Report to the State level in the same time period * 100
Proportion of cases of diseases targeted for elimination, eradication and any other diseases selected for case-based surveillance reported with case-based or line-listing forms.	Target 80% Monthly	Number of diseases targeted for elimination, eradication, and any diseases selected for case-based surveillance reported with case-based forms or line List in a given Time period ÷ Number of diseases targeted for elimination, eradication and any other disease selected for case-based surveillance in the same time period * 100

Indicator	Target	Calculation
Proportion of investigated outbreaks with laboratory results	Target 80% Monthly	Number of investigated outbreaks with laboratory Results in a given time period ÷ Number of investigated outbreaks *100
Proportion of confirmed outbreaks with a nationally recommended public health response	Target 80% Monthly	Number of confirmed outbreaks with a nationally Recommended public Health response in a given time period ÷ Number of confirmed outbreaks *100
Case fatality rate for each epidemic prone disease reported	Depends on disease	Number of Deaths from each of the epidemic-prone diseases in a Given time Period ÷ Number of Cases from the same epidemic-prone disease in the same time period *100

- *Source: IDSR Objectives and Current Implementation, WHO, 2018*