
Effectiveness of a Mobile Short-Message-Service–Based Disease Outbreak Alert System in Kenya

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We conducted a randomized, controlled trial to test the effectiveness of a text-messaging system used for notification of disease outbreaks in Kenya. Health facilities that used the system had more timely notifications than those that did not (19.2% vs. 2.6%), indicating that technology can enhance disease surveillance in resource-limited settings.

Outbreaks of epidemic diseases pose serious public health risks (1). Kenya, like other Africa countries, lacks the means to deliver adequate healthcare services. This weakness compromises the success of the World Health Organization's Integrated Disease Surveillance and Response (IDSR) and International Health Regulations (IHR) strategies and often results in incomplete, delayed, and poor-quality (i.e., not following standard case definitions in the IDSR guidelines) paper-based reporting from health facilities in remote areas. Furthermore, inadequate reporting limits health managers' ability to take appropriate and timely action in response to health events (2,3).

Widespread expansion of mobile phone coverage in Africa (4) offers opportunities to overcome weaknesses in health systems and to improve medical and public health practice through mobile health (mHealth) (5). Despite many mHealth projects undertaken in Africa, their effectiveness has rarely been rigorously evaluated, limiting evidence-based policy adoptions or project expansion in scope or geography (6–9). In particular, evidence of effectiveness of mHealth interventions for enhancing disease surveillance is scarce (10). We undertook a clustered, randomized, controlled trial with 135 health facilities in Busia and Kajiado Counties in Kenya during November 2013–April 2014 to test the effectiveness of a mobile short-message-service (SMS)–based disease

outbreak alert system (mSOS) for reporting immediately notifiable diseases.

The Study

mSOS is a formatted text-messaging system that enables communications between healthcare facility workers and Ministry of Health managers and uses a Web-based portal to monitor disease notifications and response actions taken by health managers (Figure 1; online Technical Appendix, <http://wwwnc.cdc.gov/EID/article/22/4/15-1459-Techapp1.pdf>). In our trial, health workers used mSOS for 6 months to send information about suspected cases or health events that required notification within 24 hours. Twelve diseases and conditions were selected for the study (online Technical Appendix Table 1). Before mSOS was implemented, we conducted a 1-day refresher training course on IDSR for in-charges (i.e., medical officers in charge) of 135 participating health facilities; the training focused on case definitions of notifiable diseases and on paper-based reporting. During the training, facilities were randomized into intervention and control groups; the intervention group received an additional day of training on mSOS. Paper-based reporting continued throughout the study period for both groups, so the intervention group would report cases 2 ways.

Our primary outcome was determining how many of the cases that required immediate notification were reported within the time specified. Our secondary outcome was determining, from among the cases for which notifications were sent, the proportion for which response actions were taken. For evaluation purposes, data from health facilities were collected for 6-month periods before and after the intervention launch (i.e., IDSR and mSOS training and use of mSOS for 6 months). Cases detected, notifications submitted, and responses undertaken were extracted from facility records in both study groups. Notifications sent by SMS were retrieved from the mSOS system. Our primary analysis was intention-to-treat (i.e., analysis of cases from all health facilities as they were randomized, regardless of intervention exposure). Our secondary analysis was per-protocol (i.e., our trial protocol) and was restricted to cases reported by facilities whose in-charges had received training (i.e., IDSR training for control group; IDSR and mSOS training for intervention group; Figure 2).

Characteristics of health facilities and in-charges were similar; data from preintervention and postintervention

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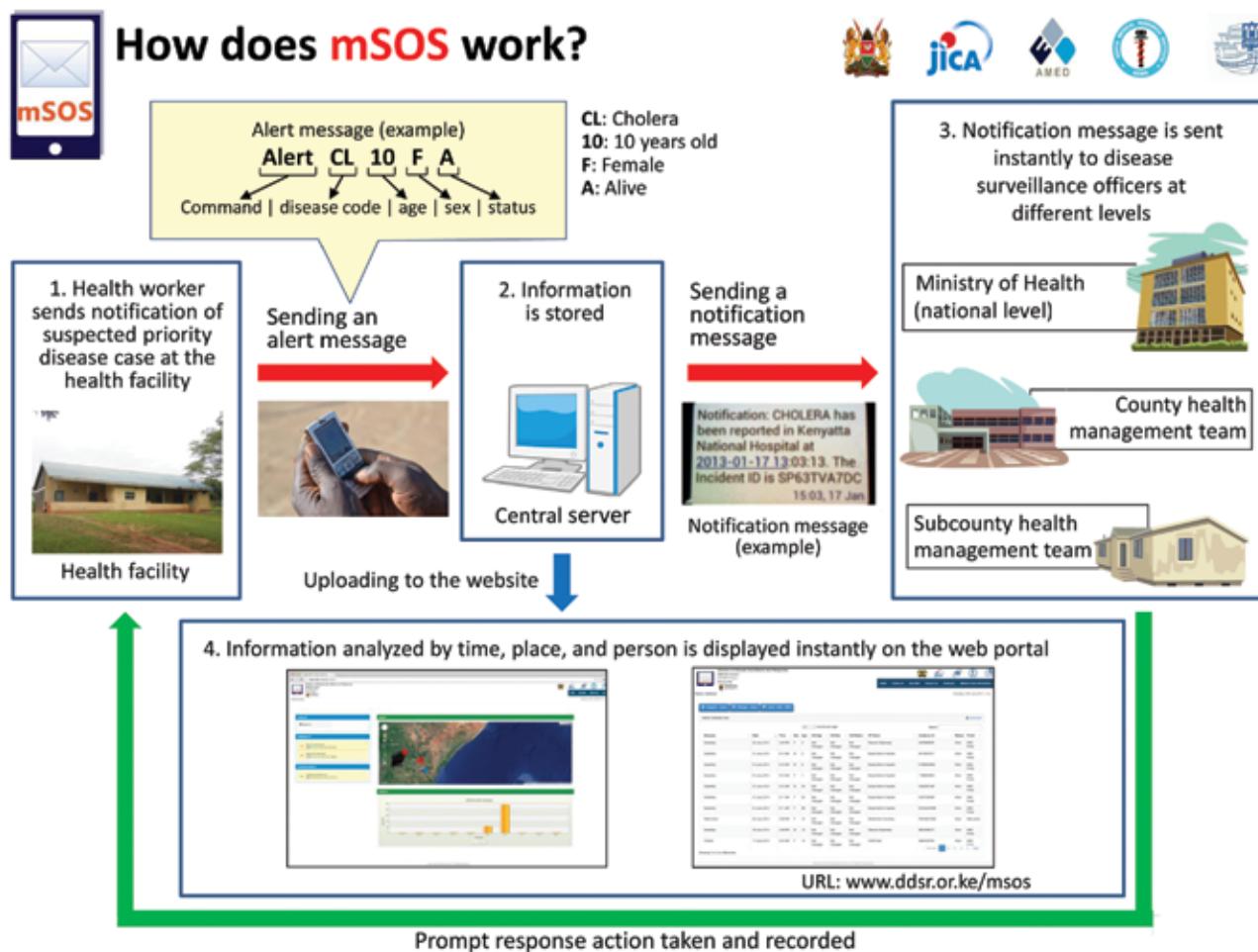


Figure 1. Structure and communication flow of a mobile short-message-service–based disease outbreak alert system (mSOS) in Kenya. Source: mSOS Technical Working Group, Ministry of Health Kenya.

surveys showed no significant differences between control and intervention groups (Table 1). Follow-up surveys conducted 6 months after the intervention showed that 34 (51.6%) of 66 intervention group in-charges received mSOS and IDSR training and 32 (49.2%) of 65 control group in-charges received IDSR training (Figure 2; online Technical Appendix).

A retrospective review of the baseline (preintervention) surveys showed that 36 cases (19 for intervention group, 17 for control group), all measles, required immediate notification. Of these 36 cases, only 1 immediately notifiable case was reported (from a control facility using paper forms). During the 6-month period after the intervention, 169 immediately notifiable cases (130 for the intervention group, 39 for the control group) were detected: 160 measles, 6 anthrax, 2 Q fever, and 1 guinea worm. Of the 39 cases detected in the control group, notification of only 1 case (2.6%), which was measles, was sent. Of the 130 immediately notifiable cases detected in the intervention group, 25 (19.2%) were reported to disease surveillance

coordinators at the subcounty, county, and national levels. This proportion of cases reported was significantly higher than that reported by the control group (% difference 16.7, 95% CI 2.71–25.07; Table 2).

All 25 cases for which notifications were sent from the intervention group were measles cases reported through mSOS; 2 cases were also reported with paper forms. For these 25 mSOS notifications, the threshold for a measles outbreak response (5 suspected cases) was met once, and disease surveillance coordinators at the subcounty level responded to this event. Furthermore, 24 (96%) of the 25 suspected measles cases were reported within 24 hours.

In the per-protocol analysis, the percentage of cases for which notification was sent was greater in the intervention group than in the control group (27.3% vs. 4.8%), but the difference was of borderline statistical significance (% difference 22.5, 95% CI –0.32 to 34.13 by Wilson procedure with continuity correction [11]). Similar differences were found when the analysis was restricted to health

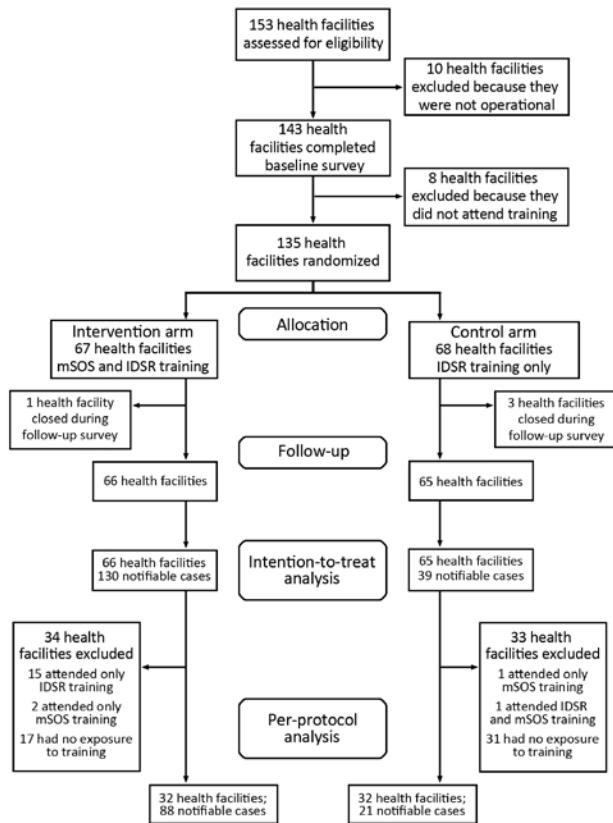


Figure 2. Profile of control and intervention health facilities and exclusions during the course of a study of a mobile short-message-service-based disease outbreak alert system (mSOS) in Kenya. IDSR, Integrated Disease Surveillance and Response.

facilities that stocked paper-based tools (i.e., control group, 1/18 [5.6%] vs. intervention group, 22/78 [22.6%]; % difference 17.0, 95% CI -2.93 to 35.30).

Conclusions

This study showed that SMS intervention significantly increased timely notifications; however, despite a relatively large improvement, response remained suboptimal, with timely notifications of only one fifth of detected cases. These findings mirror results of a study in Tanzania, which showed that SMS considerably increased vital registration coverage but fell far short of reporting actual birth and death events in the community (12).

Our study has implications for health managers who implement interventions to improve disease surveillance in resource-limited settings. First, the number of detected cases requiring immediate notification increased postintervention. This effect was observed in both intervention and control groups but was higher in the group using SMS; this group had a 7-fold increase in detected

cases compared with baseline findings. IDSR refresher training may have contributed to increased case detection, and the combined interventions, including the technology component, resulted in a greater detection effect. Second, expecting health workers to complete paper-based forms and deliver them without incentive within 24 hours is ineffective for ensuring notification of cases, with or without exposure to the refresher training. Third, we observed a large drop-out rate (47.4%) for health facility in-charges participating in the study. The study took place during a period of health management decentralization in Kenya, resulting in 47 new counties and in health worker transfers. Lack of on-the-job training for staff who did not attend the training and lack of support through posttraining follow-up and supportive supervision were weaknesses in the intervention. These systemic challenges, reported in other IDSR (13) and mHealth surveillance (14) projects, must be addressed to avoid compromising the sustainability of such interventions. Finally, attrition of health workers exposed to the intervention and lack of paper-based tools explain only part of our results. The short duration of the training deployed (15) and the possibly suboptimal quality of the training delivered (3) may have contributed to the unrealized full potential of the intervention.

Despite its limitations (online Technical Appendix), this study shows how technology in the form of mSOS can increase the rate of notifications of suspected disease outbreaks and enhance IHR compliance in resource-limited settings. Further investigation into ways to optimize the quality of delivery of mSOS interventions in countries with weak healthcare systems is justified.

Acknowledgments

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Table 1. Characteristics of health facilities and their in-charges for intervention and control groups and study periods, Kajiado County, Kenya*

Characteristic	Preintervention, no. (%)		Postintervention, no. (%)		p value†
	Control, N = 65	Intervention, n = 66	Control, n = 65	Intervention, n = 66	
Health facilities, Kajiado County	42 (64.6)	41 (62.1)	42 (64.6)	41 (62.1)	0.767
Ownership					
Public	39 (60.0)	45 (68.2)	39 (60.0)	45 (68.2)	0.329
Private	15 (23.1)	13 (19.7)	15 (23.1)	13 (19.7)	0.637
FBO/NGO	11 (16.9)	8 (12.1)	11 (16.9)	8 (12.1)	0.435
Level of care					
Hospital/health center	20 (30.8)	19 (28.8)	20 (30.8)	19 (28.8)	0.804
Dispensary	40 (61.54)	43 (65.15)	40 (61.5)	43 (65.2)	0.668
Other facility	5 (7.7)	4 (6.1)	5 (7.7)	4 (6.1)	0.712
Resource availability					
Mobile phone	65 (100)	66 (100)	65 (100)	66 (100)	–
Electricity	45 (69.2)	47 (71.2)	54 (83.1)	49 (74.2)	0.217
Water	54 (83.1)	47 (71.2)	51 (78.5)	50 (75.8)	0.713
Surveillance focal person	48 (73.9)	44 (67.7)	44 (67.7)	47 (71.2)	0.662
IDSR reporting tool‡	22 (33.9)	23 (34.9)	34 (52.3)	32 (48.5)	0.662
IDSR job aid	44 (67.7)	44 (66.7)	49 (75.4)	55 (83.3)	0.261
Characteristic of in-charge					
Female sex	32 (49.2)	39 (59.1)	32 (49.2)	39 (59.1)	0.257
Median age, y (IQR)§	34 (29–48)	35 (30–42)	36 (30–49.5)	37 (30–44)	0.677
Doctor/clinical officer	12 (18.5)	15 (22.7)	16 (24.6)	13 (19.7)	0.498
Nurse	46 (70.8)	48 (72.7)	44 (67.7)	48 (72.7)	0.529
Other healthcare worker	7 (10.8)	3 (4.6)	5 (7.7)	5 (7.6)	0.980

*The table does not show data for Busia County because values will be inverse of data for Kajiado County (i.e., N minus n). N = total facilities in both counties. The intervention group is the group of facility in-charges who were exposed to IDSR and mSOS training and to the mSOS intervention; the control group is the group of in-charges who were exposed to IDSR training only. FBO, faith-based organization; IDSR, Integrated Disease Surveillance and Response; in-charge, medical officer in charge of facility; IQR, interquartile range; NGO, nongovernment organization.

† χ^2 test was used to compare the proportions between control and intervention groups. Wilcoxon Mann Whitney test was used to compare medians between control and intervention groups (i.e., age of in-charges). Analyses were conducted by using an α level of 0.05. The p value is shown for the postintervention period only.

‡Standardized IDSR paper-based reporting form for immediately notifiable diseases.

§Data are median and Interquartile range rather than numbers and percentages. Denominator excludes 3 facilities with missing values in the preintervention control group and 1 facility with missing values for each of the remaining 3 study groups.

Table 2. Postintervention reporting of immediately notifiable cases by study group under the intention-to-treat and per-protocol analysis*

Type of analysis	Control		Intervention		% Difference (95% CI)
	Total	Cases notified, no. (%)	Total	Cases notified, no. (%)	
Intention to treat	39	1 (2.6)	130	25 (19.2)	+16.7 (2.71–25.07)
Per protocol	21	1 (4.8)	88	24 (27.3)	+22.5 (–0.32 to 34.13)

*Intention-to-treat analysis indicates analysis of treatment groups as they were randomized, regardless of the intervention exposure; per-protocol analysis indicates restricted analysis of groups that completed the entire study according to the trial protocol.

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Technical Appendix

Additional Details of the mSOS Study in Kenya

Detailed Methodology

Study Sites

The study took place at health facilities in Busia and Kajiado Counties in Kenya. These counties were selected because of historic records of outbreaks of viral hemorrhagic fevers (1,2). Busia County borders Uganda by the Victoria Lake basin; has a population of 740,043; covers a surface area of 1,134 km²; and is divided into 7 subcounties that represent first-level health management units in Kenya. Kajiado County, which borders Tanzania, has a population of 682,123; a surface area of 2,190 km²; and 5 subcounties. The World Health Organization's Integrated Disease Surveillance and Response (IDSR) was implemented in both counties in 2005. In alignment with national guidelines for reporting suspected immediately notifiable diseases, IDSR involves completing and submitting paper-based forms from rural health facilities in Kenya to the subcounty-level disease surveillance coordinators, who electronically transmit information to higher-level managers and provide the first-level response action to the reporting facilities (3).

Study Participants

Participants in the study included in-charges of health facilities that were registered on the official Ministry of Health Kenya Master Facility List (4) operational during the study period. These facilities provided curative services and were operated by government, faith-based, nongovernmental, or private organizations. Absence of a mobile phone network at the facility and the inability of facility in-charges to use short-message services (SMS) were exclusion criteria.

Intervention

The intervention was a mobile SMS-based disease outbreak alert system (mSOS), which was developed by the Ministry of Health (MOH) in collaboration with the Faculty of Information and Technology at Strathmore University in Nairobi and was pretested and refined at several health facilities before training and deployment began in the study areas. The mSOS consisted of formatted SMS communication between health workers at local facilities and MOH managers at the subcounty, county, and national levels. A web-based mSOS portal was developed and used to monitor notifications sent by health facility workers and response actions taken by the national disease surveillance officers and managers (Figure 1 in main text). Health workers used an mSOS text messaging system for 6 months to send patient-level information for suspected cases that required immediate (i.e., within 24 hours) notification. Twelve diseases and conditions listed in the national IDSR guidelines were selected for the study (Technical Appendix Table). Text messages sent by health workers consisted of prescribed codes specifying patients' disease diagnosis, age, sex, and survival status (i.e., alive or dead). The messages were sent to a toll-free number set up by a telecommunication provider in Kenya. Health managers at all levels received text messages in real time on their mobile phones. By using a password-protected web-based portal, they could also observe all notifications, maps with locations of health facilities where incidents occurred, and graphs showing cumulative cases reported. All information sent by mSOS was stored on a secure server at the MOH.

Before mSOS was implemented in the study areas, a 1-day IDSR refresher training for all in-charges of health facilities was conducted during September and October 2013. The training focused on case definitions of notifiable diseases and routine paper-based case notifications. During the training, health facilities were randomized into control or intervention groups, and participants from the intervention group facilities received an additional day of training on using mSOS. During the mSOS training for health workers, the subcounty and county disease surveillance coordinators were also trained on how to access and use the web-based portal to view mSOS information and how to log the response actions taken. Throughout the study period, the paper-based reporting, as indicated in the national IDSR guidelines, continued in both the intervention and control facilities; the intervention group was also trained to use mSOS to report the same cases reported by paper.

Randomization and Masking

Randomization was conducted during the IDSR training by stratifying health facilities by subcounties and randomly selecting intervention facilities from each stratum by using a 1:1 ratio. The intervention group was unmasked because of the nature of the study; investigators, health workers, and health managers were observing SMS notifications and were aware of which study facilities were in the intervention group.

Data Collection

To evaluate the intervention, pre- and post-intervention surveys were undertaken by the health facilities. In June 2013, baseline retrospective data were collected for the 6-month period before the intervention (December 2012–May 2013). In May 2014, the data were collected for the six-month duration after the intervention was launched (November 2013–April 2014). At each study facility, trained data collectors reviewed all outpatient, inpatient, and maternal and child health registers and extracted patient-level information for the 12 diseases and conditions selected for the study. For each extracted case, date of patient's visit, name, sex, age, and provisional diagnosis were recorded. Copies of submitted paper-based reports for immediately notifiable diseases were also reviewed. In addition, the visitors' and supervision books signed by surveillance coordinators were reviewed at the health facility to determine whether any response action was taken at the health facility after the notification was sent.

For the intervention group, notifications sent through mSOS were also extracted. During the surveys, all in-charges of health facilities were interviewed, and information on characteristics of the facility and of the in-charges managing the facility and their exposure to the intervention was recorded. Data extracted from facility records were collected on paper forms, and data from structured interviews with facility in-charges were collected by using Magpi software (5) installed on data collectors' mobile phones.

Definitions

A case requiring immediate notification was defined as any of 12 notifiable diseases and conditions extracted from any of the facility registers. Data from the source documents were examined to eliminate duplicate cases by using patient's diagnosis, date, and name. Notifications were defined as cases reported through paper-based forms in the control group and mSOS or paper forms in the intervention group. A response action taken was defined as visits to the reporting facility by the subcounty, county, or national surveillance coordinators,

as documented in visitors' or supervision books in the control group or through the mSOS web portal or visitors' or supervision books in the intervention group. According to the national IDSR guidelines in Kenya, the 12 notifiable diseases and conditions, except for measles, required immediate notification within 24 hours of detection, and response action was required within 24 hours of notification. Measles required immediate notification within 24 hours of detection, and response action was required within 24 hours of notification of the fifth suspected measles case detected in the same health facility or subcounty during 1 month. The number of notification days was calculated as the period of days between the date of case detection and the date of notification.

Statistical Analysis

All analyses were performed by using Stata version 12 (College Station, Texas, USA; <http://www.stata.com/>). The primary analysis was "intention-to-treat" and included cases from all study facilities as the facilities were randomized, regardless of the intervention exposure. The secondary analysis was "per-protocol" (i.e., study protocol) and was restricted to the cases from the facilities where the facility in-charges were exposed to the IDSR training in the control group and to IDSR and mSOS training in the intervention group. An additional analysis in which per-protocol conditions were further restricted to the case-patients seen at health facilities with available paper-based tools was also performed. To explore potential confounders, the χ^2 test for proportions and the Wilcoxon Mann Whitney test for median comparisons were conducted on characteristics of health facilities and of their in-charges to compare the control and intervention groups. Because no significant differences were found and only 1 notified case across study groups was reported at baseline, results from the post-intervention survey under the intention-to-treat and per-protocol analyses were the primary focus of results (presented in this article). Because of the small population sizes for both analyses, which precluded cluster adjustments, we calculated the 95% CIs around differences in proportions between notification outcomes for the intervention and control groups by using the Wilson procedure with continuity correction (6,7). CI estimations were done at an α level of 0.05.

Ethical Considerations

Ethical approval was obtained from Kenya Medical Research Institute (KEMRI) Ethical Review Committee (SSC 2523). The trial is registered with Current Controlled Trials

ISRCTN 79529838. Written informed consent was obtained from all health facility in-charges enrolled in the study for baseline and follow-up surveys.

Trial Profile

Figure 2 shows the trial profile, including characteristics of nonexposure and contamination (i.e., when facility in-charges crossed from the intervention group to the control group or vice versa during the study period) of the trial facilities 6–8 months after delivery of the intervention. Before the study began, 153 health facilities from the Master Facility List were assessed for eligibility in the study areas. Ten facilities were excluded because they were nonoperational at the time of the study. The baseline survey was therefore undertaken at 143 health facilities. Of 143 facilities, in-charges of 135 facilities attended the training, where 67 and 68 facilities, respectively, were randomized into intervention and control groups. Four facilities had closed by the time the follow-up survey was undertaken 6–8 months later. The follow-up survey included 131 health facilities, of which 66 from the intervention group and 65 from the control group were included in the primary, intention-to-treat analysis. Of the 66 facilities in the intervention group, the follow-up survey showed 34 (51.6%) facilities with in-charges who received the complete intervention: both IDSR and mSOS training. The other in-charges in the intervention group either did not attend the study training (17 [25.7%]) or attended only either the IDSR component (15 [22.7%]) or the SMS component of the training (2 [3.0%]). As with the intervention group, only 32 (49.2%) of 65 facilities in the control group had in-charges who received routine IDSR training during the intervention delivery. Because of transfers of health workers, 2 facilities in the control group were also found to be contaminated with in-charges who were exposed to the SMS component of the intervention. The restricted per-protocol analysis included 64 health facilities (32 in the intervention group and 32 in the control group).

Limitations

This study has several possible limitations. First, we did not capture possible informal notifications through phone calls or in-person interactions between health facility in-charges and disease surveillance coordinators at the subcounty, county, and national levels. This lack of information may have underestimated the true rates of managers' awareness about immediately notifiable cases, but the information collected in the study reflects the true degree of compliance with the IDSR national guidelines. Second, the lack of completeness of notifiable cases recorded by health workers in the source documents at the health facilities is an inherent problem and may have resulted in selection bias. Such bias was partly remedied

through the randomized design. Finally, the study did not verify whether the diseases recorded in the source documents were correctly diagnosed or recorded on the basis of case definitions or laboratory confirmations; these verification measures were beyond the scope of the study.

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Technical Appendix Table. List of 12 immediately notifiable diseases included in the study of a mobile short-message-service-based disease outbreak alert system in Kenya*

Name of disease or event
Adverse events following immunization
Anthrax
Cholera
Dengue fever
Guinea worm
Measles
Neonatal tetanus
Plague
Rift Valley fever
Viral hemorrhagic fever
Yellow fever
Any public health event of international concern (e.g., infectious, zoonotic, foodborne, chemical, radionuclear, or caused by an unknown condition)

*The 12 diseases and conditions were selected from the World Health Organization's Integrated Disease Surveillance and Response national guidelines for Kenya.