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Evaluation of Short Message Services (SMS) based data collection system for the surveillance in Nepal.

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Abstract

Evaluation of Short Message Services (SMS) based data collection system for the surveillance in Nepal.

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Introduction:

Natural disasters increase the risk of morbidity and mortality caused by communicable disease without a well-understood mechanism. The devastating earthquake in Nepal had escalated the threat of disease outbreaks in these areas. Nepal is endemic for many communicable diseases including cholera.

Evidence from past experiences has established the importance of infectious disease surveillance to protect survivors during disasters. Real-time monitoring of morbidity can provide early signs of outbreaks, providing an opportunity to prevent outbreaks.

Epidemiology and Disease Control Division (EDCD) of Nepal Government started syndromic surveillance right after the earthquake along with pre-existing Early Warning and Reporting System (EWARS). “Timeliness” and “Completeness” of reports were the two major problems faced by these surveillance systems. The adaptation of electronic records had shown improvement in timeliness and completeness of reports as well as increased breadth and depth of information collected. The ICD coded health record used

for surveillance had been demonstrated as an effective method. Health Management Information System (HMIS)'s register number 1.3 (HMIS1.3), records socio-demographic, geographic information along with ICD 10 coded working diagnosis, making it a perfect record for syndromic surveillance. Hence, the study explored the opportunity of using digitalized HMIS1.3 with minimal modification and transmitted via SMS for a surveillance system.

Objective:

This study aims to develop SMS based syndromic surveillance system and evaluate the feasibility of SMS-based health record collection for surveillance.

Methodology:

For the purpose, mobile phones with the android platform were selected, as they are cheap and easily available in developing the world. Opendatakit (ODK) collect, widely used open source data collection app developed by the University of Washington was customized to incorporate SMS capabilities. The de-identified individual record form outpatient register (HMIS 1.3) was collected digitally via android app and transferred via SMS to the main server. The system was used for six weeks (from 22nd Feb to 4th April 2016).

Center for Disease control and prevention (CDC)'s framework for surveillance system evaluation was used. The framework had recommended nine attributes for surveillance but as our system was in early stage of implementation suitable four attributes namely, Timeliness, Data Quality (Completeness, Error Rate), Acceptability (cost of SMS) and Simplicity (Ease of Use) were selected.

Metadata related to date and time was used for calculating timeliness. Data elements were categorized as compulsory and optional to calculate completeness. Patient counseling was video recorded and reviewed for error rate calculation. The cost of SMS per individual's record was calculated using a mean number of characters in SMS received. A self-administered questionnaire was used for ease of use.

The system was tested in "Bahunepati Health Center" and "Thangsen Health Center", rural health centers from a network of eighteen health centers of Dhulikhel Hospital-Kathmandu University Hospital, Nepal. Bahunepati Health Center lies in Sindupalchowk district which was hit with a maximum number of aftershocks and Thangsen Health Center lies in Nuwakot District which is adjacent district hit by largest magnitude earthquake.

Results:

During the study period, 459 cases were reported via SMS. The mean time required to fill digital form was 109.3 seconds (SD 182.75) and median time required was 67.25 seconds, difference in mean time required to fill digital form was nominal between two outreach centers. Similarly, mean transmission time was 447.85 seconds (SD 637.71) and median for the parameter was 226 seconds. There is a noticeable difference in mean and median transmission time between outreach centers, for Bahunepati Health Center mean was 569.03 seconds (SD 676.11) and the median was 346 seconds whereas for Thangsen Health Center mean was 26.7 seconds (SD 58.96) and the median was 12 seconds. All the report submitted was 100% complete and error rate was found to be 1.95%. The error was on geographic information and ICD classification. The cost for transmission of data per patient was NRs. 4.26 (equivalent to USD 0.04). The mean user rating of parameters for

ease of use was high with the mean point of 6.6 out of 9. Two parameters "overall flexibility" and "performance of the task is straight forward" got a rating below 6.

Discussion and Conclusion:

The surveillance system introduced had made complete data from individual patients available for the analysis within few minutes of entry with minimum error. The study demonstrates the feasibility of using SMS based syndromic surveillance with acceptable cost and addressing the problem faced by current surveillance system in Nepal i.e. completeness and timeliness of data.

Keywords: syndromic, surveillance, Nepal, Data quality, Evaluation, SMS, Mobile

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Introduction

1.1 Background

Natural disasters increase the risk of morbidity and mortality caused by communicable diseases. A water-borne diseases like diarrheal diseases, acute respiratory infections, vector-borne diseases etc. have been recognized as the major killers in the post-disaster situation(*1*). Natural disasters such as flood was found to increase mortality rate by 50% in the first year, without the well-understood mechanism of long-term health effects (*2*). Poor availability of sanitation facilities and safe water has been recognized as the major factor behind post-disaster outbreaks. (*2, 3*). Earthquake is the second most reported natural disaster after the flood (*4*). Earthquake-associated mortality generally progresses in well-defined phases that ultimately give way to longer-lasting periods of new and complex health needs. The first phase is caused by the immediate kinetic trauma. The second is a product of infectious complications from the bodily trauma. The third is linked to infectious disease outbreaks enabled by the destruction of water and sanitation infrastructure, substantial displacement of the population (*4, 5*).

The devastating earthquake of 2015 in Nepal had resulted in approximately 9,000 deaths and 23,300 injuries. Nearly 594,000 houses were destroyed affecting 8 million people including 1.1 million children in a total 14 districts. (*6*). Over 2.8 million people were displaced (*7*) and 503 health facilities had been completely destroyed (*8*). This had escalated the threat of disease outbreaks in these areas.

Many of the outbreak-prone infectious diseases are endemic in Nepal like Hepatitis E and cholera. At least one major outbreak of cholera per year are reported to World Health

Organization (WHO) in last five years (2009 to 2014). Acute Respiratory infections, seasonal influenza, meningococcal disease, measles, malaria etc. are among other most probable post-disaster outbreak disease. The map (figure 1) presents potential risk of a cholera outbreak, mapping epicenters of earthquakes and historical cholera outbreaks in Nepal. (*5*, *9*)

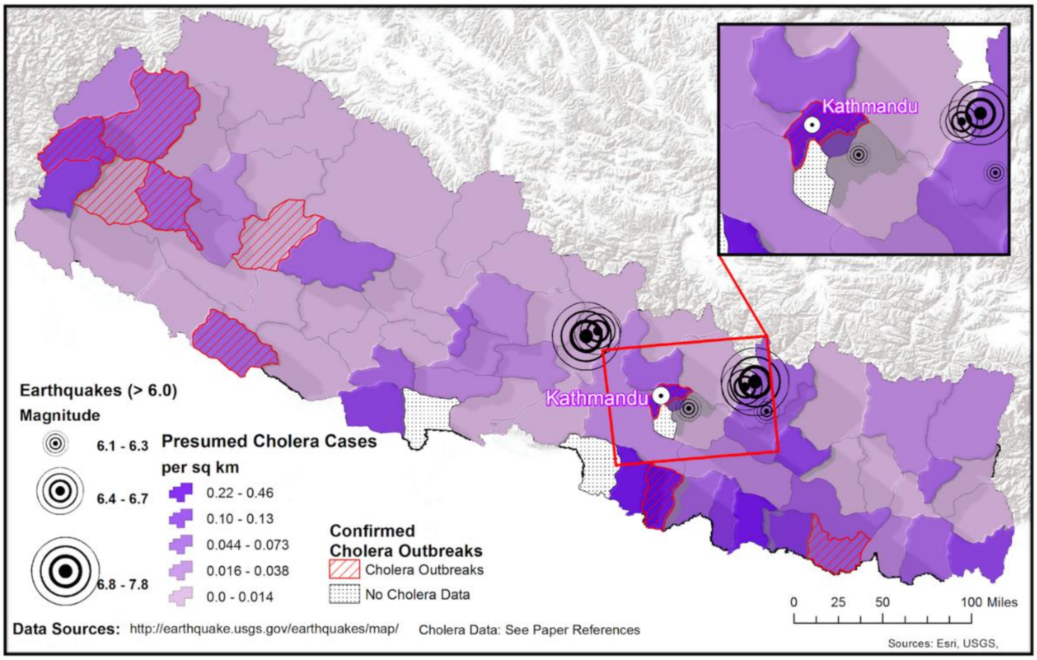


Fig 1. Epicenters and Historical Outbreaks of Cholera in Nepal (Source: (5))

Evidence from past experiences has established the importance of infectious disease surveillance to protect survivors during disasters. WHO considered surveillance as the cornerstone of public health security. Surveillance generally includes the systematic on-going process of collection, analysis, interpretation and dissemination of health data essential for the planning, implementation, and evaluation (*10, 11*) . Real- time monitoring of morbidity can provide early signs of outbreaks, which will be very helpful for the prevention of disease. Current advancement in technology (especially Information

Technology) had vast potential to improve health and medical responses to natural disasters(*12*).

Conventional surveillance relies on voluntary data submission of clinical and laboratory confirmed the reportable and unusual disease. The time required for reporting and the epidemiological analysis, delayed the process of outbreak detection and alert public health offices for action. The nature of data and time consumption for processing those data makes conventional surveillances methods less useable(*13*).

In contrast, syndromic surveillance which got attention after used against bioterrorism utilizes new information infrastructure and method for timely detection and monitoring. The system relies on detection of clinical case feature that is discernable before confirmed diagnoses (*14*). Non-dependency on laboratory confirmation along with the use of auto detection and alerting algorithms speed up data collection, analysis, and alerting process, making this system more reliable for emergency conditions. Choice of datasets used by the syndromic surveillance makes it independent from the pre-defined categories. These properties had made it a better choice for developing and under-developed countries with limited laboratory facilities (*15*). Nepal also lacks laboratory capacity outside Kathmandu valley (*5*), and there is less possibility to diversify the data sources, but International Classification of Disease (ICD) coded data are recorded and reported from the lowest unit of health facilities. Hence, there is high chance to utilize that sources to introduce syndromic surveillance.

Epidemiology and disease control division (EDCD), the government institution responsible for surveillance, had revived and started three surveillance system in co-operation with private and international community after earthquake (*16*), continuing pre-existing Early Warning and Reporting System (EWARS) along with introduction of "hospital-based sentinel syndromic surveillance system" and "Active surveillance for cholera in Kathmandu valley". EWARS is the surveillance system in Nepal for outbreak-prone infectious diseases. This is hospital-based sentinel surveillance system and currently operational in 40 hospitals. There is provision for weekly and immediate reporting based on nature of the disease being reported. (*17*, *18*). Along with EWARS, Post-Earthquake hospital based syndromic system had also been started in 14 hard hit districts and active surveillance of cholera in Kathmandu valley had also been undertaken. (*17*).

Timeliness and completeness of reporting, accuracy and specificity of the coding of the data, availability of risk factor information and cost of data collection are among the challenges faced by the majority of the surveillance system (*19*). The 34th epidemiological week's (2015) EWARS report highlights these challenges exist in the surveillance system. It shows around 10.5% hospital sites did not report. Among those reported, timeliness score of 40% of hospitals was bad and 10% of hospitals was satisfactory. Similarly, completeness score for 20% was bad (<50%) and 5% hospital was satisfactory (50-79%). None of the hospitals have 100% timeliness and completeness score.(*17*).

Evidence had shown that use of electronic records (health or medical or laboratory) had yield improved timeliness and completeness of the reports as well as increased breadth and depth of the information collected(*19*-*21*). Various studies had also tried to use ICD coded hospital records for the surveillance, which are proven to be feasible with satisfactory results. (*22, 23*). This adds more support on the feasibility of syndromic surveillance from rural health centers of the Nepal. Transfer of the health record possesses challenge for implementing the system.

Viewpoint published in PLOS neglected tropical disease had highlighted about approaches that can be adopted in resource-limited settings, classifying them into high tech, med tech and low tech models of the surveillance system. High tech model with smartphone and decision support. Medium-tech model with the utilization of hotline phones for communication, a Paper-based record at the origin and electronically enters data in higher centers. Low tech model with traditional paper-based system and communication is also by the ground transport. High tech model is dependent on the 3G network which is limited in Kathmandu only. Mid tech seems more reliable but might have a problem due to telephone congestions experienced after every major aftershock. Low tech is very slow and labor intensive but this only options in few mountain areas without phone network penetration. (*5*). The current system used in Nepal mostly falls under mid tech or low tech model.

Different implementations in the developing countries had adopted Short Messaging Service (SMS) based approaches for the data transmission. The "Surveillance in Post Extreme Emergency and Disaster" (SPEED) implemented in the Philippines also utilized SMS as a major way for data submission along with other methods. Similarly, the approach was also used in Sichuan earthquake and found to be very effective (*24-26*). During non-disaster situation, the approaches had been used in different countries from Asia like (Sri-Lanka, Indonesia, India, Bangladesh etc.) to Africa (Kenya, South Africa etc.). The approach had been found to be effective in timely submission of the reports whereas there are mixed results in error rate. Cost, mobile network coverage, electricity access and high personnel turnover were perceived as major challenges. (*27-30*).

Considering all the facts related to Surveillance system, data source, Implementation models and infrastructural challenges, the system that can be worked in limited connectivity environment, electronic, can use the previously existing formats and less dependent on electricity might be useful for Nepal to fight against the wave of epidemic of infectious disease triggered by the earthquake. Hence, this study has digitalized the out-patient record making it usable in android devices and transfer of the de-identified patient to cloud server via SMS. All of the SMS-based system reviewed had found to be using separate surveillance forms, in our knowledge, this was first attempt to transfer section of regular health record via SMS, feasibility related to this kind of approaches haven't been explored yet. This study will design "SMS based syndromic surveillance" using health record from rural health centers and to explore the feasibility of use of SMS based system in terms of cost, timeliness, effectiveness and perceived ease of use by implementing Android based data collection tool in rural health centers of Nepal.

1.2 Objective:

1. To Design SMS based syndromic Surveillance system

2. To evaluation feasibility of Mobile based health record collection and transfer via SMS

1.3 Limitations:

Due to the limitation of time and resources, we were not able to implement the whole system in Nepal. Hence, only mobile based system will be tested in two health centers. The work for further development will be continued based on this idea and will be communicated.

Literature Review

Availability of mobiles is increasing worldwide. Many peoples had adopted this booming technology for the health sector too, so we have lots of examples of adaptation of mobile based system in health. In this chapter, we will look into few of that system which has a close link with this study.

Open Data Kit (ODK) is an extensible open-source tool for building information services in developing countries. The tool was developed by the University of Washington sponsored by google.org. The toolkit had three components, build to make the forms, collect (an android based app) for data capturing and aggregate for hosting and gathering surveys. ODK collect is capable of collecting the data offline and sync when connected to internet.(*31*). ODK is one of the most widely used and customized tools in the field of mobile data collections. Kobotoolbox, formhub, Ona, elmo are few names of projects which are built on top of ODK. Few adaptations had tried to include SMS functionality in ODK collect like a Medic collect project from medic mobile, a non-profit organization.

SMS gateways are another important part of my study. In this area, FrontlineSMS and RapidSMS are two of the projects which are mostly being used. Lots of tools in health and other domain had adopted these technologies. (*32*, *33*). RapidSMS based mTrac, a Health Management Information System (HMIS) based surveillance system is being operational in Uganda. The system had been designed for real-time data collection, verification, accountability and analysis of aggregate data and community engagement for the improvement of healthcare service delivery. (*34*)

The Analytical module is another important component in the surveillance system. Johns Hopkins University's Applied Physics Laboratory had developed "Suite for Automated Global Electronic bioSurveillance (SAGES)" as a collection of modular, flexible, freely available software tools for the electronic disease surveillance in resource-limited settings. The module includes openEssence (Electronic Surveillance system for Early Notification of Community-Based Epidemics) software available in desktop and server versions along with mobile based collection tools. The tools had been tested in a different context and also been used by Missouri Department of Health and Senior Services. The tool uses inputs from electronic emergency department (ED) data for the purpose of syndromic surveillance. (*35*-*37*)

Electronic Health Record (EHR) Support for Public Health (ESP) is another open-sourced disease surveillance system developed by Harvard Medical School's Department of Population Medicine. The system extracts and analyze events of public health importance and securely submit the report to the government authorities. The major aim of the system is to shift the burden of the reporting from clinician to information system. (*38*). Both ESP and SAGE OpenEssence make use of different algorithms for auto detection of outbreaks.

In the context of Nepal, lots of SMS base project had been initiated. Medic mobile and one heart worldwide (OHWW) had used SIM applications and text forms for SMS-based monitoring of community-based maternal and child health. The pilot was conducted in Baglung and Dolpa districts. (*39*). The SMS-based technology is also being used in immunization-preventable disease monitoring like Acute Flaccid Paralysis (AFP) and Measles as well as during the immunization campaigns for adverse effect reporting. (*40*). National Health Education information and communication center along with support from

USAID, GIZ , and UNFPA had adopted SMS based mHealth approach to educating on the reproductive health in Nepal. These are few major projects in Nepal using SMS-based technologies but reports on the use of SMS as the study proposed use hadn't been found.

Methodology

This chapter provides a general overview of Health Management Information System (HMIS), the main system of recording and reporting of health data in Nepal and how the SMS based surveillance system had been developed with its root in HMIS system and the methods used to collect the data and analysis of the information.

Context

Nepal government had developed a set of tools for capture and communicate health and related records which are known as Health management information system (HMIS) tools. The HMIS tools contain 50 different tools. Tools used to record patient information are known as registers and tools used to report the information to the higher centers are named as forms. All HMIS tools are coded and each tool is used to record the specific health-related event, like out patient's record are captured in register with code number HMIS 1.3 including detail demographic and morbidity information. (Please refer to figure 2).

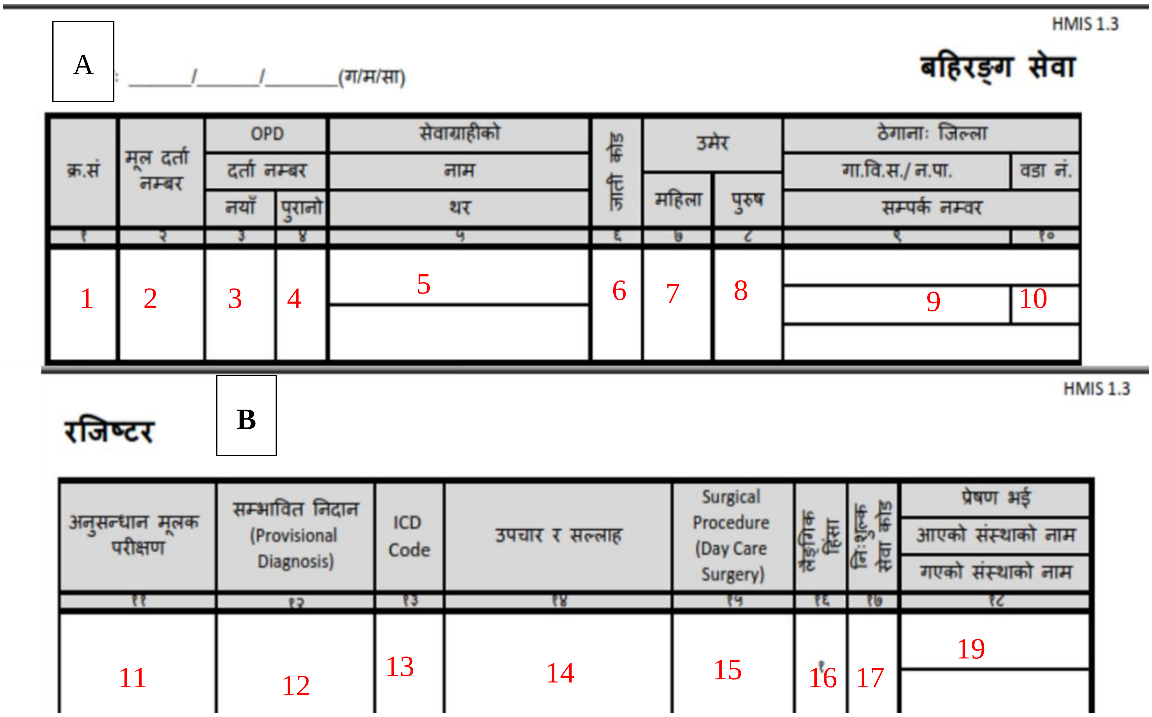


Fig 2. HMIS 1.3 (Outpatient Register), A: contains column 1 to 10 given in table 1 along with the date on the top. B: contains column 11 to 18.

Column	Recorded Variables
1	Serial Number
2	Registration number
¾	OPD registration type (3.New or 4.Old)
5	Name and Caste of patients
6	Ethnic code
7/8	Age segregated age by (7. Female and 8. Male)
9/10	Address (9. Village and 10. Ward)
11	Investigative test ordered
12	Provisional Diagnosis
13	ICD 10 code for Provisional Diagnosis
14	Treatment and advice provided
15	Surgical procedure (day care surgery)

16	Case related to gender-based violence
17	Free Health service card
18	Referrals (Name of organization referred from / to)

Dhulikhel Hospital-Kathmandu University Hospital also follows HMIS guidelines for recording health-related events in its rural health centers. Morbidity register used at DHKUH's rural health centers is equivalent to HMIS1.3. The information collected in these register meets the minimum data set required for syndromic surveillance as recommended by International Society for Disease Surveillance (ISDS).(*41*). Hence, the surveillance system was designed to digitalize and utilize information from HMIS1.3.

3.1 Study Design

This study is explorative study.

3.2 Participants/Study Population

The study population will be healthcare providers at Thangsen Health Center and Bahunepati Health Center and Outbreak Prevention and Management Unit(OPMU), Department of Community Programmes. These institutes are part of Dhulikhel Hospital-Kathmandu University Hospital.

3.3 Selection Criteria

Following inclusion criteria was set forward for selection of participants and site:

1. Participants must be health care provider of selected health institutions or member of OPMU

2. Participants must have used SMS-based data collection tool at least for a day.
3. Study institutions must have at least 2G mobile network and remain operational.

3.4 Sampling Method/Technique

The purposive sampling was used. Dhulikhel Hospital was selected as the study site. The rural health center which meets inclusion criteria were selected purposively with the permission from Department of Community Programmes, Dhulikhel hospital.

3.5 Study Site and Justification

Dhulikhel Hospital – Kathmandu University Hospital (www.dhulikhelhospital.org) was selected as the study site purposively. The hospital is not for profit, non-government, community hospital which acted as the *de facto* command center for the management of rescued victims from Sindhupalchowk, Kavre, Dolakha, Ramechhap and Sindhuli districts in the east of Kathmandu during Nepal earthquake 2015.

Sensing high risk of the post-disaster disease outbreak, Hospital had formed outbreak prevention and management unit (OPMU) under the leadership of Department of community programs including public health experts, doctors, nurses, microbiologists and health educators. The team were trained and highly motivated to prevent outbreaks.

Dhulikhel Hospital has a network of eighteen rural community-based health facilities (as shown in the figure below). Two of the outreach centers are selected for the implementation. The health centers were selected on the basis of ease of access and from the earthquake hit site. The details about the selected outreach centers are given in table1.

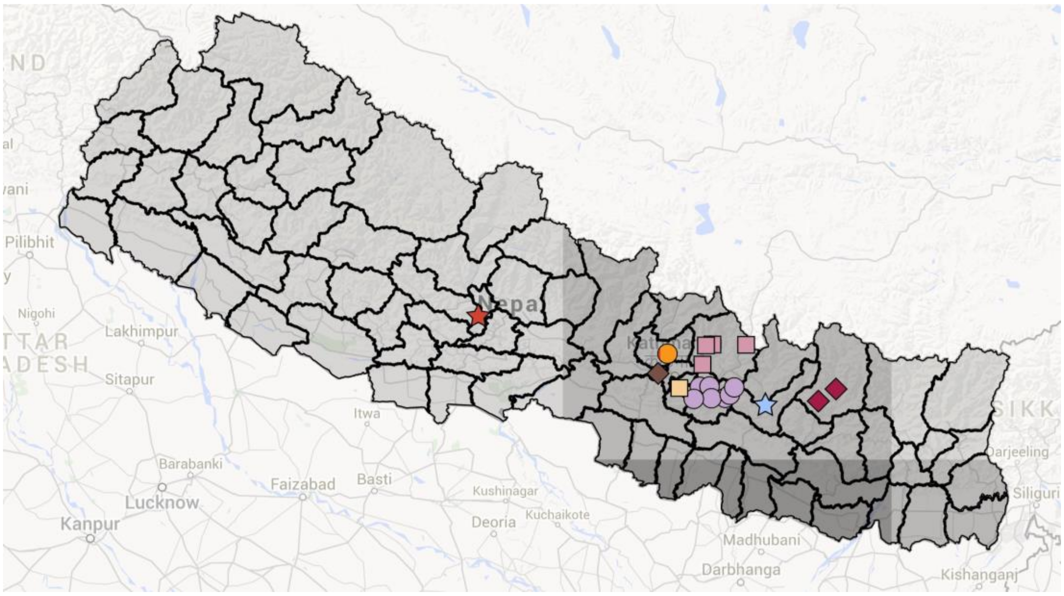


Fig 3. Different rural health centers' of Dhulikhel Hospital

Table 1: Selected Health Center for mobile based data collection experimentation.

SN	Health Center	Ward	VDC/ Municipality	District	Household*	Population*
1	Bahunepati	2	Basbari	Sindhupalchok	1102	5056
2	Thangsin	7	Thangsing	Nuwakot	1388	6126

**source: National Population and Housing Census 2011 (Vol 2)*

Bahunepati Health Center lies in Basbari village of Melamchi Municipality, Sindupalchok district around 60KM in the northeast of Kathmandu and Thangsin Health Center lies in Thangsin Village Development Committee (VDC), Nuwakot district around 70KM in the north of Kathmandu. Both of the selected health centers were highly affected by the earthquake and near to epicenters.

3.6 Data Collection Methods:

Various methods, video recording, metadata review, data review and self-administered questionnaire were used in the study. Video recording and reproduction of paper-based format was used for calculating an error rate. Metadata related to date and time was used for calculating timeliness, each record within the study period was observed for the completeness. A self-administered questionnaire was used for ease of use survey.

3.7 Procedure/Process

The implementation of the surveillance system is based on winning idea of "#Hackthequake 2015" (idea completion organized to minimize the effect of the earthquake in Nepal, organized by Nepal Engineers Association). The surveillance system was designed with 3 components, data collection platform (android based app), Data communication platform (SMS gateway and/or internet) and Analytical modules, as shown in the figure below. But the scope of this study is limited to evaluation of data collection and data communication.

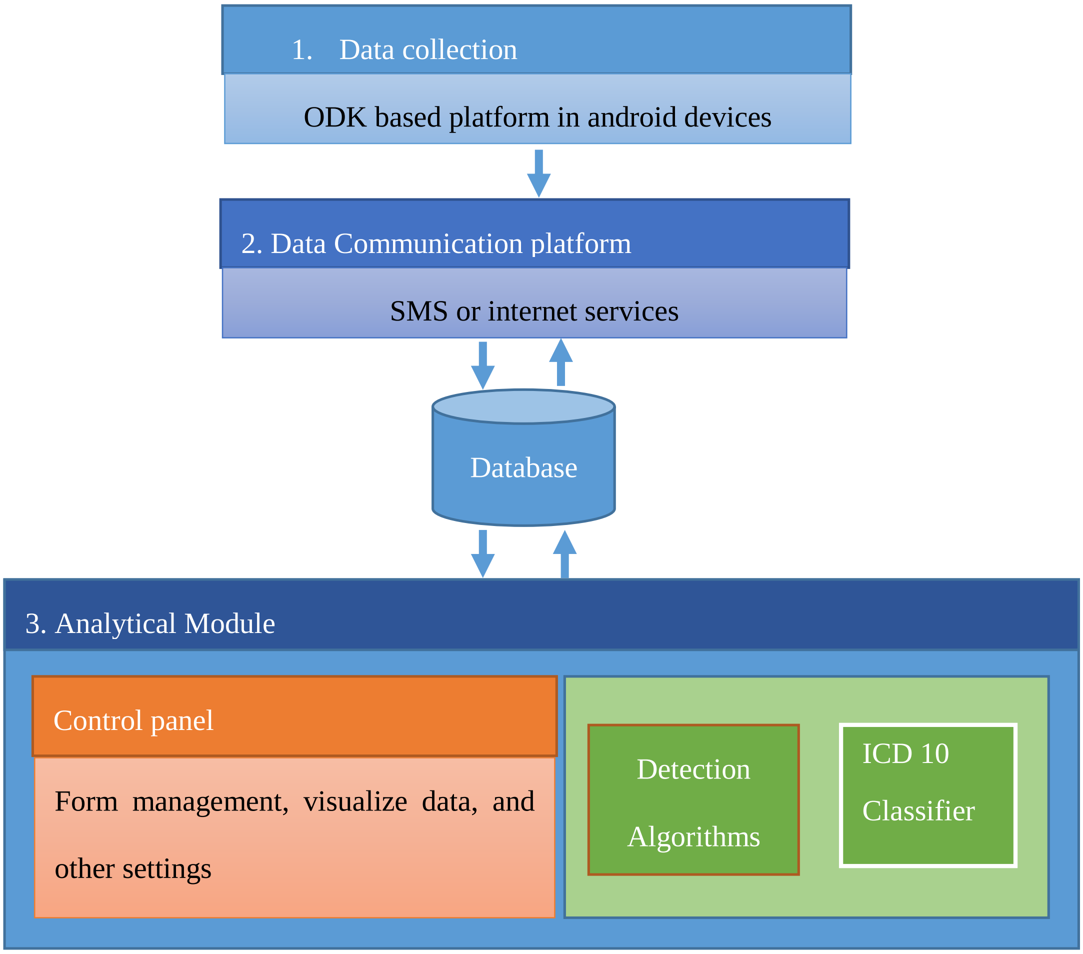


Fig 4. Architecture of SMS based Surveillance System

3.7a Data collection:

3.7a.1. Android App: Open Data kit (ODK) collect is android based data collection tool developed by the university of Washington, which had been widely adopted by organizations, research institutes working in resources limited settings. ODK collect is the part of series of tools develop by this team. ODK collect can collect the data without connectivity and transfer the data via internet later. The possibility of data communication via SMS would have added an extra value to the ODK collect to work in limited connectivity settings. Various open source projects are being undertaken to add SMS functionality in ODK collect. Medic Mobile (http://medicmobile.org/) is among one of leading organizations in this area. Adopting their source code customized version of ODK collects with SMS functionality was build. The app was customized to make it handle short code and keywords from the commercial service provider and customized SMS phrasing.

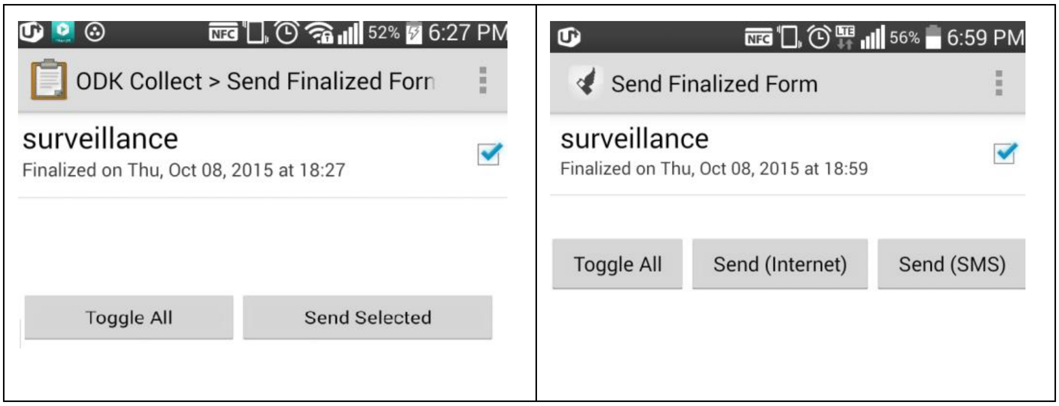


Fig 5. Screenshots from ODK Collect (on left) and customized version for surveillance (on right). The customized version has sent via SMS option.

The ODK uses XML file to store the data temporarily in android device whereas customized version use XML as well as the .txt file. The .txt file contains SMS parsed message, which will be used to send an SMS message. (Please refer to Annex II)

3.7a.2 Form Designing: The ODK collect renders form written in XForms standard. The paper based morbidity register and OPMU surveillance form were reviewed and data elements were finalized for the form. The form was designed in using XLSform in google sheets. (Please refer to Annex III)

3.7a.3 Mobile Phone: The Huawei G Play mini, manufactured by Huawei Consumer Business Group which runs android 5.1 (lollipop) with the 5-inch display was used in the study. (http://consumer.huawei.com/en/mobile-phones/tech-specs/g-play-mini-en.htm).

3.7b Data communication:

SMS was selected as the means of data communication because of two reasons. First, the internet is not reliable outside the Kathmandu valley but have reliable 2G network coverage. Secondly, mobile service was restored within few hours after the main earthquake and other major aftershocks. Shortcode and SMS gateway serveries from commercial value added service (VAS) provider Eprima (http://epirma.com.np) was used for the data communication. The shortcode is a special telephone number significantly shorter than the general mobile number used especially for SMS and SMS gateway allows a computer to send or receive SMS transmission to and/or from a telecommunication network.

3.7c Analytical Module:

The analytical module includes form management, data visualization, Detection algorithm, ICD 10 classifier and access control. The customized version of kobotoolkit (kobotoolkit.org) was used for the form management, CUSUM based outbreak detection algorithms C1, C2, C3 was used. The module was mostly developed using python. The Analytical module doesn’t fall under the scope of this study, so further details will be discussed in next study.

3.8 Evaluation and Analysis

The SMSs received was pulled using APIs provided by the gateway and parsed, stored in the relevant field and analyzed using open source software R. The analysis was undertaken following standard guidelines.

The Center for Disease Control and prevention (CDC)'s guideline for the evaluation public health surveillance system is a most adopted framework in this area. The guideline had identified nine attributes for evaluation (*42*). As The surveillance system under evaluation is in initial (early) implementation stage all attributes are not appropriate, hence, four appropriate attributes were selected (*43*) namely, timeliness, data quality, acceptability and simplicity.

3.8a Timeliness:

The guideline had defined the timeliness as speed between steps in a public health surveillance system and can be measured via time interval linking any two of steps public health surveillance. In this study, data acquisition and transfer steps were taken into account.

The time required to fill up the form was regarded as data acquisition time and the interval between completion of form filling and SMS delivered at servers is regards as transmission time. Form fill-up time was calculated using auto recorded start and end time for form fill-up. The health center staff were requested to send the forms as soon as the form was completed. The time interval between form fills up end time and message received time on another side(server) was regarded as the time for the transmission. Mean data acquisition time and mean data transmission time were used as an indicator for the timeliness. (*43*)

The data records submitted between 22nd February and 23rd March 2016 was used to calculate the Timeliness. For comparison purpose time required for filling paper, the register was also recorded in Thangsen on 22nd February and Bahunepati on 23rd February

2016. According to the protocol of OPMU Data were being transmitted once a week, making a comparison of the data transmission time invalid.

3.8b Data quality:

Data quality was defined as completeness and validity of the data. The majority of studies in data quality in public health had represented completeness as a percentage of blank or unknown data, non-zero/missing or proportion of filling in all data elements in the form (*42*) (*44*). MEASURE Evaluation, Routine Data Quality Assessment document had used validity and accuracy interchangeably and defined as the data measures what it intended to measure (*45*). For this study we consider completeness as a proportion of blank (NA) data among compulsory data elements and validity of data as Error rate was measured comparing the information received via SMS with paper-based record reproduced.

In most of the previous studies, the records were first made in the paper-based system and then re-entered into the SMS-based system for transmission of the report and error rate was calculated by comparing the report received in SMS and paper records. We simulated paperless experience to health workers. The health workers directly used android based system as the primary record during the consultation with the patient. The video of consultation was recorded with permission from patients protecting their privacy. The video and other notes made during the consultation was reviewed by the colleague and reproduce paper based record. The error rate is calculated based on these two record. This technique was adopted to minimize workload and ensure minimal effect in regular administrative function of the health center.

3.8c Acceptability:

Acceptability is defined as the willingness of persons and organizations to participate in the surveillance system. The point of interaction between the system and its participants is focused for a measure of acceptability. (*42*) System cost isn't considered as attributes but taken into account for evaluation under system experience. Cost borne by the data provider and societal perspective of cost (e.g cost of prevention and treatment born by the community) (*46*). The acceptability of system by the organization is influenced by the system cost. Thus, the cost was calculated as the proxy measure for the acceptability. The societal perspective of cost calculation requires long-term data hence the recurrent cost of the system; data transmission cost is only taken into consideration in this study. The cost required for data transmission was calculated on the basis of the maximum length of SMS, the cost of SMS and projected number of patients reviewing historical data of the health center.

3.9d Simplicity:

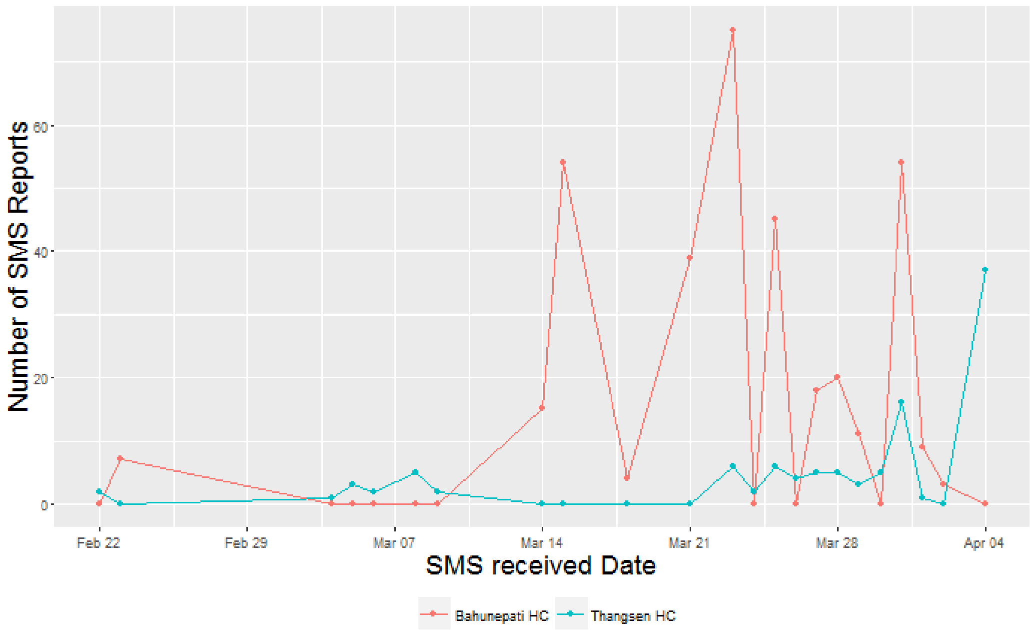
The simplicity is defined as structure and ease of use of the surveillance system. In this study, we focused on the ease of use and perception of users. The standard questionnaire was adopted to test the ease of use. Self-administered questionnaire survey and unstructured discussion were made with users for this purpose. (Please referred to annex for the questionnaire)

Findings and Results

4.1 General Characteristics

The data was collected using multiple tools, methods, and duration between 22nd Feb and 4th April 2016 total of six weeks. During this time, 459 cases were reported through the SMS, 105 cases from Thangsen Health Center and 354 cases from Bahunepati Health Center.

Fig 6. Number of reports received at server from outreach centers by date



The message was found to be sent mostly by two staffs only (one from each outreach center). In Bahunepati Health Center 98.87% of reports were found to be sent by staff with code 1413, Similarly, in Thangsen Health Center 99.05% of reports were sent by staff with code 2028.

Fig 7. Number of Reports send by Staff ID from both outreach center

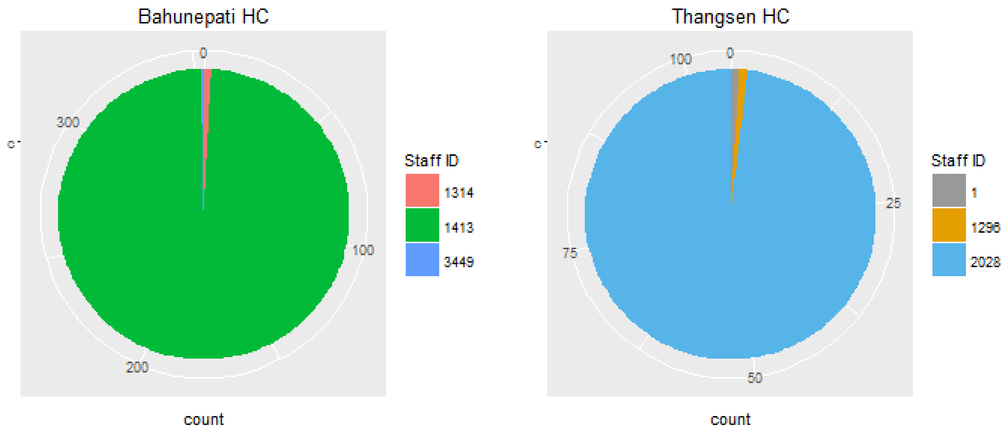
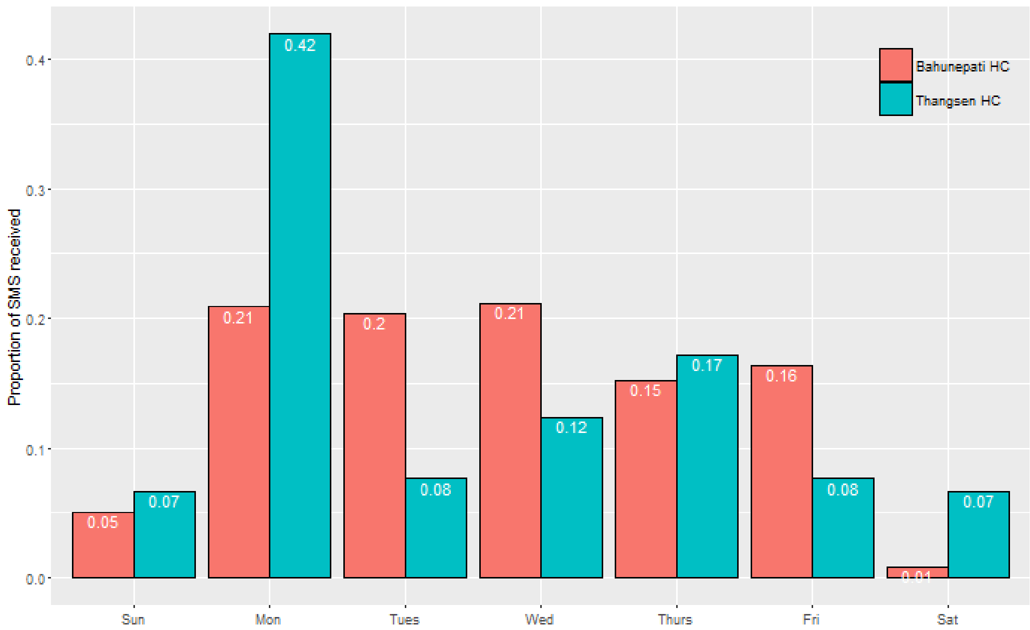


Fig 8. Proportion of SMS Received by Days of the Week



Distribution of the report received with days of the week shows some variability in Thangsen Health Center where as Bahunepati Health Center have less variability. The maximum proportion of the report was received on Monday for Thangsen Health Center and least on Saturday for both health center.

4.2 Timeliness:

Timeliness was measured for two aspects of surveillance. First, one is the time required for fill up digital forms and the second one is the time required to get data in the main server after completion of fill up, termed as transmission time.

4.2.1 Time required filling digital form

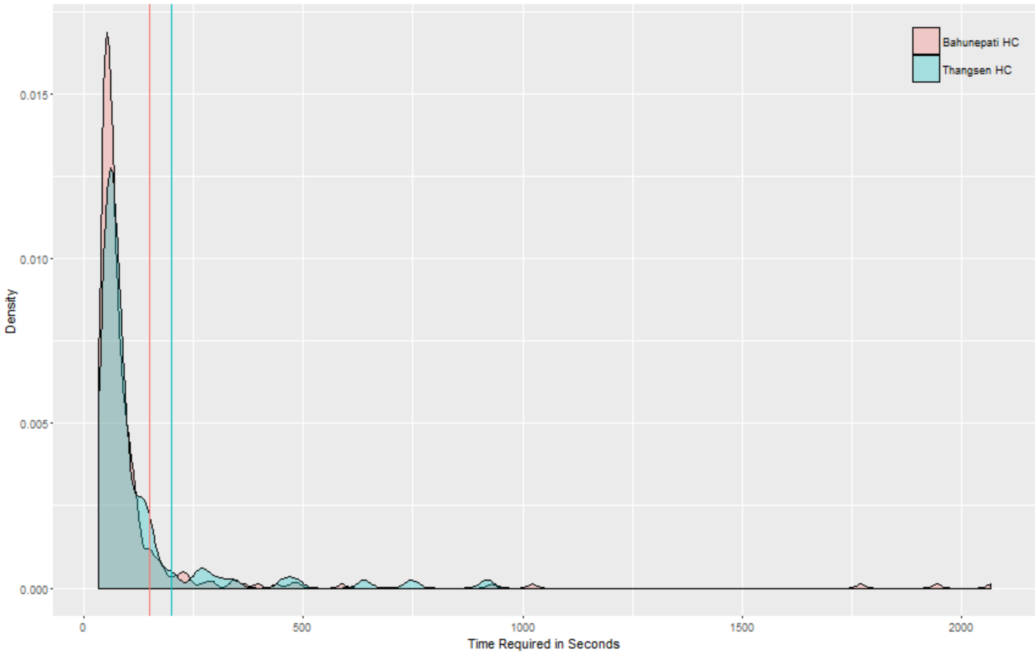
The mean time required to fill the digital form was found to be 109.3 seconds with a standard deviation of 182.75. It was found to be 106.85 seconds (SD 194.26) for Bahunepati Health Center and 117.51 seconds (SD 137.59) for Thangsen Health Center. The median time was found to be 67.84 Seconds for both Health centers where as 64.84 seconds and 72.44 seconds for Bahunepati and Thangsen Health Center respectively.

Table 2: Mean Time Required to fill Digital Form in Mobile (n=458)

OUTREACH	MEAN TIME (SECS)	SD	MEDIAN (SECS)
BAHUNEPATI HC	106.85	194.26	64.84
THANGSEN HC	117.51	137.59	72.44
TOTAL	109.3	182.75	67.25

The density plot reveals that there is the very low density of observation in right. 90% of the observation are under 200 seconds.

Fig 9. Density plot of Time Required to fill Digital Form in Mobile with 90th Percentile vertical line



4.2.2 Transmission Time: Time required to get data in the main server

Transmission time was measured as the difference in time between completion of data fill up and SMS received on the server. The shortest transmission time recorded was seven secs whereas longest time recorded was 3739 secs. The mean transmission time was found to be 447.85 secs (SD 637.71), median transmission time was found to be 226 secs. The server received 90 percent of collected data within 1038 seconds of completion. The mean transmission time for Thangsen Health Center was 26.7 secs (SD 58.96) which are 21 times less than Bhanuepati Health Center (569.03 Sec with SD 676.11). Similarly, Median transmission time also shows similar variation between health centers, 12 secs for Thangsen Health Center and 346 secs for Bahunepati health Center. The 90 percent of reports from Thangsen Health Center delivered to the server within 48 secs, but it took 1219 secs in the case of Bahunepati.

Table 3: Transmission Time: Time required to get data on the main server from the point of form completion in seconds

OUTREACH	MEAN	SD	MEDIAN	PERCENTILE (90TH)
BAHUNEPATI HC	569.03	676.11	346.00	1219.00
THANGSEN HC	26.70	58.96	12.00	48.00
TOTAL	447.85	637.71	226.00	1038.80

4.3 Data quality

The completeness was measured with 6 weeks' data and error rate was calculated with data from a single day.

4.3.1 Completeness

Completeness was measured as a portion of blank data elements. The form has a total of 22 data elements, among them 16 are mandatory and 6 are conditional data elements. Hence, completeness was measured against those 16 mandatory data elements. There aren't any blank data elements in all reports during the study period. So, the completeness was 100 % for the reports received.

4.3 .2 Error Rate

The error rate is measured comparing the data received via SMS and paper-based record reproduced. Among thirteen patients visiting during the study period, Seven Patients permitted for the video capture. In Bahunepati Health center, one data element from three patients record was found to be different in reproduced paper-based record and SMS received. The errors were found in data elements "Name of Village"," Ward Number" and

"ICD10 classification of Disease". The error rate was calculated to be 1.95% (3 error data element /22 data elements x 7 patients).

4.4 Acceptability

4.4.1 Cost of Transmission

The cost required of SMS per message is considered as a cost of transmission which is a major recurrent cost for this project. The cost was calculated using a mean number of character in SMS message and SMS rate. The mean character in SMS was 212.7, One SMS can contain 160 characters that make two SMS per the report submitted. The rate of SMS in shortcode is Nepalese Rupee 2.13 including government tax. Hence, the total cost for sending report is Nepalese Rupee 4.26

4.5 Simplicity

Perceived simplicity was measured through a self-administered questionnaire. Four out of five health service providers working in Thangsen (2 out of 2) and Bahunepati (2 out of 3) health center participate in the survey. The questions related to Overall reaction to APP, Screen, and Forms, System Information, Learning and System capabilities were included. The mobile app got the satisfactory score in evaluated areas. Overall Flexibility and Performance of task is straight forward got the lowest mean scores (i.e. below 6 out of 9).

The staff had found the list of diagnosis codes not sufficient and difficult for them to limit the given list. Finding districts and villages from a long list and long time required to fill up forms had been reported as the downside of the system, but It has been welcomed as a new concept. Data stored in digital format and possibility of editing data are reported as a positive aspect of the system.

Table 4: Response to usability question survey posed to staff at Health Centers of Kathmandu University Hospital - Dhulikhel Hospital

VARIABLE (SCORE FROM 0 TO 9)	MEAN	SD	MEDIAN	SE
OVERALL REACTION TO APP				
DIFFICULT TO EASY	7.25	0.96	7.5	0.48
FURSTATING TO SATISFYING	6	1.83	6	0.91
RIGID TO FEXIBLE	5.75	2.06	6	1.03
SCREEN AND FORMS				
READING CHARACTER ON SCREEN (EAST TO HARD)	7.5	2.38	8.5	1.19
TERMS USED IN FORMS	6.25	2.22	6	1.11
SEQUENCE OF DATA ELEMENTS IN FORM	6.25	3.1	7	1.55
SYSTEM INFORMATION				
INFORMS ABOUT ITS PROGRESS (NEVER TO ALWAYS)	6.5	1.91	7	0.96
ERROR MESSAGE (UNHELPFUL TO HELPFUL)	6.5	2.65	7	1.32
LEARNING				
TO OPERATE THE SYSTEM	7	1.41	7.5	0.71
EXPLORING FEATURES BY TRAIL AND ERROR	6.5	1.29	6.5	0.65
PERFORMING TASK IS STRAIGHT FORWARD	5.5	2.38	5.5	1.19
HELP MESSAGE(HINTS) ON THE SCREEN	7.25	1.5	7	0.75
SYSTEM CAPABILITIES				
FORM LOADING (TOO SLOW TO FAST)	6.75	1.5	7	0.75
SYSTEM RELIABILITY (UNREALIABLE TO RELIABLE)	6.25	2.06	6.5	1.03
CORRECTING YOUR MISTAKES (DIFFICULT TO EASY)	7.75	1.5	8	0.75

Discussion

5.1 Discussion

The complete and timely data plays a vital role in surveillance, however, surveillance system implemented after the earthquake in Nepal had both of these problems. Our study aims to present proof of concept of feasibility to adopt SMS based surveillance system in addressing this problem in disaster hit Nepal.

Surveillance systems are implemented based on two models of data processing, a centralized processing model and distributed processing model for public health surveillance. Both has its pros and cons. Centralized Processing model collects individual Personal Health information (PHI) with a certain level of identifiable information, which possesses the risk of disclosure. Whereas, distributed processing model moves some of the initial data processing to the site where data is being collected limiting the risk of disclosure but make it difficult for update software and statistical methods. (*47*). Nearly nonexistence of Electronic Medical Records (EMRs) in rural health centers. The manual collection and aggregation of data demand additional labor and time. Hence, study digitalizes HMIS1.3, a morbidity register which records socio-demographic information and working diagnosis coded in ICD 10 to collect data and transmit to central server following the centralized processing model, with a certain level of risk of discloser of semi-identifiable personal health information.

With the wide adaptation of EMR in a rural health center in future, there is a need to direct linking the EMR to the surveillance system. Currently, the proposed system doesn't have any mechanism to get data directly from EMRs. Few studies had introduced the independent software module to extract information from EMR, format HL7 message and transmission to center.

The preliminary implementation results demonstrate improvement in timeliness and completeness of data for the further analysis. During six weeks of implementation in two health centers, 459 reports were received in the main server with 100% completeness and with high accuracy of 98% (nominal error rate of 1.98%). A study conducted in Kenya which compares a smartphone with a paper pen-based questionnaire and in Fiji personal digital assistant (PDA) with paper-based also found fewer errors and inconsistencies in the smartdevices-based system (*48*), (*49, 50*). The ability of the app to program skip logics, defining constraints and other quality check methods in data entry app helped in reducing the error rates. On top of that errors were further minimized by directly uploading data into database, which removes manual data entry process into the database present in paper-based system. (*49, 51*). Our study uses the video recording and review approach to finding the error rates which was not the choice of method for other studies with similar objectives. Most of other studies compare with the paper-based system. (*49, 51*)

Equipping health center staffs with SMS based surveillance tools enabled to collect and transmit the morbidity data in near real-time with 67 seconds median time to fill up digital form and 226 seconds median transmission time from the point of completion of form fill up. Making near real-time analysis of data possible within few minutes, which is also reported by other studies (*52*). However, there was a huge difference in time required for transmission of data between two outreach center. This highlights the presence of challenges which need to be explored with the most comprehensive approach in future including social and organizational factors. As health information systems' successful implementation or adaptation is determined by various social, technical and organizational factors (*53*-*55*).

Our study use SMS for the transmission of the reports as SMS is reported to be effective and accepted. Previous studies and implementations had used the SMS for data transmission focused on enabling public reporting their health status/events or health workers reporting summarized morbidity data. (*30*, *56*, *57*). Whereas in our study individual morbidity records are transferred via SMS, which is removed manual summarization of the data, reducing the workload on health workers. The study used existing morbidity register by digitalizing. The working diagnosis was coded using ICD 10 in the morbidity register.

Our study had used this ICD 10 coded data from routine morbidity register for the syndromic surveillance. Previous studies had also used a routine data source with ICD codes. The feasibility of using ICD codes and routine had been verified from a study in Canada which used ICD codes and hospitalization data for severe maternal morbidity surveillance (*58*). Another study cross-validate accurate representation of influenza-like illness using ICD9 by cross-validating with nationwide sentinel surveillance data. (*59*). Sensitivity and Specificity of surveillance system which utilizes ICD9 coded Electronic Medical Record (EMR) data was above an acceptable level (*60*).

The staff had rated data collection android app above average, which can be considered as well accepted. The major problems reported by staff were related to restriction on the use of terminologies and language. Five health service providers from two health center were supposed to report but only two of them did almost all of the reporting. The number of days without SMS reporting was also high. The study was not able to explain the human related components as the study failed to address organization and process of implementation of the system. Further study is recommended to understand the missing components for effective implementation.

5.2 Conclusion

The approach undertaken by the study had shown improvement in data quality related to completeness, timeliness, and minimum errors. The app required minimum supervision and training for successful implementation. The cost for SMS transmission of individual data is also in considerable range.

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Annex I: Data Elements

SN	Data Elements	Value Set	Notes
a	Date	Selection from calendar	Date of Encounter
b	Health Facility Identifier	Unique Facility code provided	Each health center is provided with unique outreach code.
C	Service provider Identifier	Unique provider code.	Each staff is provided with staff number by admin of Hospital that will be used
d	Main Registration ID	ID provided in the main register	The Identification provided during the registration
e	Age	Numeric	
F	Age Unit	UCUM age units	Relevant unit for age unit: Days Weeks Months Years Derived from the united code for units of measures.
g	Sex	Government given	Male Female
h	Village	Drop Down list of administrative units	The names of the village within districts are included. Filtered by the health center.

i	Ward	(Numerical)free text	Ward is a smallest administrative unit in Nepal.
j	Laboratory order	Yes/No	Indicates whether laboratory order was placed or not
k	Provisional Diagnosis	ICD10	Diagnosis without confirmative test.
k0	Diagnosis	HMIS Disease categories	HMIS had categorized
l	Advice/Treatment	Free Text	Treatment and Advice provided will be provided here.

Annex II: SMS Text and XML format to store data

Text format


```
DHSMS st#2016-03-25T15:00:21.791+09#
a#2016-03-25#
b#1#
c#1413#
d#123#
e#123#
f#1#
g#M#
h#23#
i#5066#
j#12#
k#1#
l#2#
m#2#
n#2#
o#1#
p#1#
q#1#
t#11#
u#H26#
v#2#et
#2016-03-25T15:01:05.764+09#
instanceID#uuid:b4f7b7e9-0ec8-46da-81a4-0923e4a6669f#
```


XML Format


```
<?xml version='1.0' ?>
   <survillance id="DHSMS" prefix="DHSMS ">
          <st>2016-03-25T15:00:21.791+09</st><a>2016-03-
25</a><b>1</b><c>1413</c><d>123</d><e>123</e><f>1</f><g>M</g><h>23</h
><i>5066</i><j>12</j>
          <symp>
                    <k>1</k><l>2</l><m>2</m>
          </symp>
          <diaGrp>
                    <n>2</n><o>1</o><p>1</p><q>1</q>
          </diaGrp><t>11</t><u>H26</u><v>2</v>
          <et>2016-03-25T15:01:05.764+09</et>
          <meta>
                    <instanceID>uuid:b4f7b7e9-0ec8-46da-81a4-
0923e4a6669f</instanceID>
          </meta>
</survillance >
```

요약

네팔의 질병 감시를 위한 SMS 기반의 데이터 수집 체계 평가

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서론:

자연재해는 충분히 알려진 메커니즘 없이 전염병으로 인한 이환률과 사망률의 위험을 증가시킨다. 과거에 네팔에서 발생했던 대지진은 해당 지역의 질병 발생의 위험성을 악화시켰다. 그리고 네팔은 최근 콜레라를 포함한 많은 전염병으로부터 위협받고 있다.

과거의 경험으로부터 얻은 증거는 재난 중에 살아남은 생존자들을 보호하기 위한 감염병 감시 체계에 대한 중요성을 확립했다. 실시간으로 이환률을 감시하는 것은 질병 발생을 막을 수 있는 기회를 제공하면서 질병 발생의 초기 징후에 대한 정보도 제공 가능하다는 이점이 있다.

네팔 대지진 직후, 네팔 정부의 Epidemiology and Disease Control Division (EDCD) 은 기존의 조기 경고 및 보고 시스템(Epidemiology and Disease Control Division, EWARS)과 함께 질병 감시를 시작하였다. 이 질병 감시 시스템들이 직면한 두 가지 주요한 문제는 보고의 "적시성"과 "완성도"이다. 전자 기록 사용에 대한 적응은 수집된 정보의 양과 질을 높여주었으며, 보고 내용의 "적시성" 과 "완성도" 또한 개선시켰다. 본 연구에 쓰인 질병감시체계에 사용된 국제질병표준분류기준 (International Classification of Disease, ICD) 으로 암호화한 진료 기록의 효율성은 이미 증명 된 바 있다.

Health Management Information System (HMIS) 1.3 은 ICD 10 으로 암호화된 작업성 진단과 더불어 사회인구학적, 지리학적 정보를 기록하는 체계이다. 그러므로, 본 연구에서는 최소한의 수정으로 전자화된 HMIS1.3 를 테스트 해볼 수 있었고, 질병 감시 시스템을 위하여 SMS 로 송신하는 것을 테스트 해보는 기회를 가졌다.

연구 목표:

본 연구는 SMS 기반의 질병 감시 체계 개발과 SMS 기반의 질병 감시를 위한 보건 기록 수집의 타당성 평가를 목표로 하였다.

연구 방법:

위와 같은 목적으로, 본 연구에서는 중저소득국가에서 저렴한 가격으로 쉽게 구할 수 있는 안드로이드 플랫폼을 장착한 휴대폰들이 선택 되었다. University of Washington 에서 개발한 Opendatakit (ODK) collect 는 널리 이용되고 있는 공개 출처 수집을 위한 어플리케이션으로써 본 연구에서는 SMS 능력을 갖춘 형태로 사용자 맞춤화 되었다.

익명으로 처리한 개인의 진료 기록은 (HMIS 1.3) 안드로이드 어플리케이션을 통하여 디지털 방식으로 수집되었고 SMS 를 통해서 메인 서버로 송신되었다. 이 시스템은 2016 년 2 월 22 일부터 4 월 4 일까지 6 주간 사용되었다.

본 연구에서는 Centers for Disease Control and prevention (CDC)의 질병감시체계 평가를 위한 프레임워크를 사용하였다. CDC 의 프레임 워크는 질병 감시를 위한 9 가지의 속성을 권고 하였으나 본 연구의 시스템은 구현 초기 단계이므로 적시성, 데이터의 품질 (완성도, 오차율), 수용성 (SMS 송신 비용), 그리고 단순성 (사용의 용이성)을 채택하였다. 날짜와 시간과 관련된 메타데이터는 “적시성”을 계산하기

위해 사용되었고, 변수들은 완성도를 계산하기 위하여 의무적 또는 선택적으로 분류되었다. 또한 환자 상담은 오차율을 계산하기 위해 녹화되고 검토되었다.

개인의 진료 기록을 한 번 송신하는 데 발생하는 비용은 수신된 SMS 의 글자 수의 평균값을 사용하여 계산되었다. 또한 사용의 용이성을 위하여 자기 기입식 설문지가 채택, 사용되었다.

본 연구의 SMS 시스템은 네팔 둘리켈 - 카트만두대학병원의 18 개 보건진료소 네트워크에 속해있는 네팔 외곽지역의 Bahunepati 보건진료소와 Thangsen 보건 진료소 에서 테스트 되었다. Sindupalchowck 구역에 위치하는 Bahunepati 보건 진료소는 가장 많은 수의 여진을 겪은 보건진료소이다. Nuwakot 구역에 위치한 Thangsen 보건 진료소는 가장 큰 규모의 지진을 겪은 구역에 인접해 있다.

결과:

연구기간 동안, 459 건의 SMS 가 보고되었다. 디지털 형태를 완성시키기 위한 평균 시간은 109.3 초로 측정되었으며, 중간값은 67.25 초로 측정되었다. 두 outreach center 간에 디지털 형태를 완성시키기 위한 중간값의 차이는 거의 존재하지 않았다.

유사하게, 평균 전송 시간은 447.85 초로 측정되었으며 매개변수를 위한 중간값은 226 초로 측정되었다. Outreach center 간 전송 시간의 평균값과 중간값에는 분명한 차이가 관찰되었다. Bahunepati 보건 진료소의 평균값은 569.03 초로 측정되었으며 중간값은 346 초로 측정되었다. 반면에 Thangsen 보건 진료소의 평균값은 26.7 초로 측정되었으며 중간값은 12 초로 측정되었다.

제출된 모든 보고 자료들은 100% 완성되어 있었고 오차율은 1.95%로 측정되었다. 오차는 지리 정보와 ICD 분류에서 발견되었다. 환자 1 인당 데이터 송신 비용은 4.26 네팔 루피 (약 0.04 USD)가 발생하였다.

용이성을 위한 매개변수에 대한 사용자의 평가는 평균 9 점 만점에 6.6 점으로 높게 평가 되었다. 데이터의 전반적인 유동성과 과업의 수행의 명료성과 같은 매개변수는 6 점 이하로 평가되었다.

토의 및 결과

본 연구에 도입된 질병 감시 체계는 각 환자로부터 몇 분 안에 최소한의 오차 범위 내에서 분석을 위한 환자 개인의 데이터를 완성시켰다. 본 연구는 SMS 를 이용한

질병 감시 사용의 타당성을 입증하면서도 현재 네팔의 감시체계가 직면하고 있는 데이터의 완성도와 적시성 과 같은 문제들의 해결책을 제시하는 바이다.

키워드: 질병 감시, 네팔, 데이터 퀄리티, SMS, 평가, 휴대폰

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