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IMPLEMENTATION OF TELEMEDICINE SYSTEM TO IMPROVE AND EXPAND COVID-19 SCREENING AND EVALUATION: A REFLECTION ON ACTION RESEARCH APPROACH AND THE MANAGEMENT OF THE POSSIBLE SPREAD OF THE PANDEMIC

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IMPLEMENTATION OF TELEMEDICINE SYSTEM TO IMPROVE AND EXPAND COVID-19 SCREENING AND EVALUATION: A REFLECTION ON ACTION RESEARCH APPROACH AND THE MANAGEMENT OF THE POSSIBLE SPREAD OF THE PANDEMIC

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Abstract

Purpose: The purpose of this paper is to reflect on action research approach adopted in the design of the COVID-19 Online Screening and Evaluation Telemedicine Service system – a telemedicine system developed to promote the sharing of expertise and resources between the advanced COVID-19 diagnostic center in a major tertiary hospital and remote primary health centers and district hospitals in India.

Methodology: The longitudinal research within this project was used to determine whether the action research methodology affected the course of the project and its progress, helping the project team to better adapt the program to the needs of the clinicians and tackle the unexpected problems common in diagnosis and spread of COVID-19.

Findings: The study results found that implementation of the telemedicine system with the mobile application is imperative to implement social distancing and improve the growing shortage of COVID-19 diagnosis in India.

Unique contribution to theory, practice and policy: The paper contributes to the methodological design by using action research to analyze the field of practice using the telemedicine system within a healthcare diagnosis setting. This paper aims to tackle the research problem of low telemedicine use in healthcare as a whole, and more specifically within the diagnosis for COVID-19.

Key words: *Novel coronavirus; COVID-19; Action research; Telemedicine; Healthcare*

Jel: I10, I12, I14, I18

Introduction

Coronaviruses are part of the family Coronaviridae in the Nidovirales order. Corona contains crown-like spikes on the virus ' outer surface; thus, it has been designated a coronavirus[1]. Such viruses were believed to affect animals only until the world experienced an outbreak of serious acute respiratory syndrome (SARS) caused by SARS-CoV in Guangdong, China in 2002[2]. Two decades later, novel coronavirus named as coronavirus disease 2019(COVID-19) by the WHO on the 11th February 2020 emerged in Wuhan, China in December 2019 experienced an outbreak of a novel coronavirus that killed thousands within few weeks of the epidemic[3] and has rapidly spread across continents including India.

Clinical symptoms of patients with COVID-19 include fever, unproductive cough, dyspnea, myalgia, fatigue, regular or reduced leukocyte counts and radiographic proof of pneumonia, whose symptoms are similar to SARS-CoV and MERS-CoV infections[4]. Thus, while the pathogenesis of COVID-19 is poorly known, the related mechanisms of SARS-CoV and MERS-CoV still provides a great deal of knowledge about the pathogenesis of SARS-CoV-2 infection to promote identification of COVID-19. Clinical diagnosis of COVID-19 is focused mainly on epidemiological data, clinical symptoms and some auxiliary tests such as nucleic acid detection, CT screening, immune recognition (Point-of-care testing (POCT) of IgM / IgG, enzyme-linked immunosorbent testing (ELISA)) and blood culture. The clinical symptoms and signs of SARS-CoV-2 infected patients are nevertheless extremely atypical. Hence, the diagnosis of COVID-19 requires auxiliary tests, as is the epidemiological history. The combination of a growing list of complications in COVID-19, and a rising shortage of COVID-19 diagnosis centers puts a tremendous burden on the healthcare system in India.

Advances in technology pose unparalleled opportunities for those who live in remote or suburban areas to have greater access to services, particularly in healthcare settings where specialized medical services tend to be confined to tertiary hospitals. Therefore, those who live in remote or suburban areas often need to drive long distances in order to gain access to those healthcare facilities. Telemedicine, described as technologies that allow patients and clinicians to share information remotely about their state of health[5], implemented as potential solution for the growing healthcare access and medical facility shortage. The literature has examined the

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telemedicine implementation processes and concentrated on how to address the challenges of integrating telemedicine into healthcare diagnosis and treatment[6 7].

This paper proposes the telemedicine implementation at primary healthcare centers using an Action Research approach. The constructive interaction with potential COVID-19 patients in all stages of the project lifecycle would increase the access to COVID-19 diagnosis system. Using COSETS as a case study, a project that developed a telemedicine program for COVID-19 screening and evaluation in the city of Mumbai, India, this paper examined how the introduction of an Action Research approach may lead to the creation and development of a technology that is both functional and used. The paper was organized as follows: Section 1 provided a brief background of the case organization and an overview of the COSETS system. Section 2 discussed the context of action research and framework of telemedicine and tried to explain the adoption of action research approach to design and implement COSETS telemedicine system. Section 3 of the paper described the integration of mobile application and COSETS telemedicine system and how it prevented the travel and directed the suspect patient to primary care center. This section of the paper also explained the distribution of the workload between primary care center and tertiary hospitals and transfer of critical patients to tertiary hospitals. To conclude, the paper suggested the utilization of the telemedicine system with mobile application to implement social distancing and improve the growing shortage of COVID-19 diagnosis in India.

1. COSETS telemedicine system project background

The COSETS project emerged from a regional focus group set up by Octaware Technologies Limited[8] ("the company") to explore how advanced networked company's technology could support the population in suburban of Mumbai. The company is a software development and enterprise solutions firm with delivery center in India located in SEEPZ-SEZ, Mumbai serving global customers in healthcare[9], government and finance sectors. Founded in 2005, this socially-motivated and information technology company specializes in telemedicine system with the goal of improving access to healthcare in India and developing world. The flagship solution of the company, COSETS, is the fastest-growing telemedicine platform. This innovative technology solution[10] uses the power of mobile phones and internet to connect patients in suburban and remote areas with medical specialists in urban centers, enabling community-based health care professionals and patients to access their treatment without having to travel.

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COSETS is an expert telemedicine system that has Lab Test capture mechanism, processing units, data communication networks, and medical service servers. As shown in Figure 1, the Lab Test capture unit are responsible for obtaining the diagnosis data and patient's symptom and transmitting it to the data processing unit. Many research concentrate mainly on the nature of these laboratory test capturing systems to be safe and easy to use and to protect patient mobility and privacy[11]. In the next stage, for the collection, processing, analysis and encoding of data to be sent to the communication layer, the storage layer of each laboratory test capture system is usually connected to the processing unit. The processing unit will determine the state of the patient and the patterns in the medical condition. In recent telemedicine studies several medical algorithms have been developed to aid in the diagnosis of patients[12]. Telemedicine systems can be divided into two operating modes: real-time mode in which patient data is accessible on the server immediately after delivery, and storage mode in which data is retrieved at a later date. For both modes the diagnosis data are transmitted to the server by computer networks[13], wireless networks, mobile data networks[14], or cable television networks. For such system, a medical specialist is required at locations where he / she can use a computer to access the server to interpret the symptom and lab test data, and the patient is confined at a fixed location such as a home or primary healthcare center where a computer or mobile phone is designed to transmit these data.

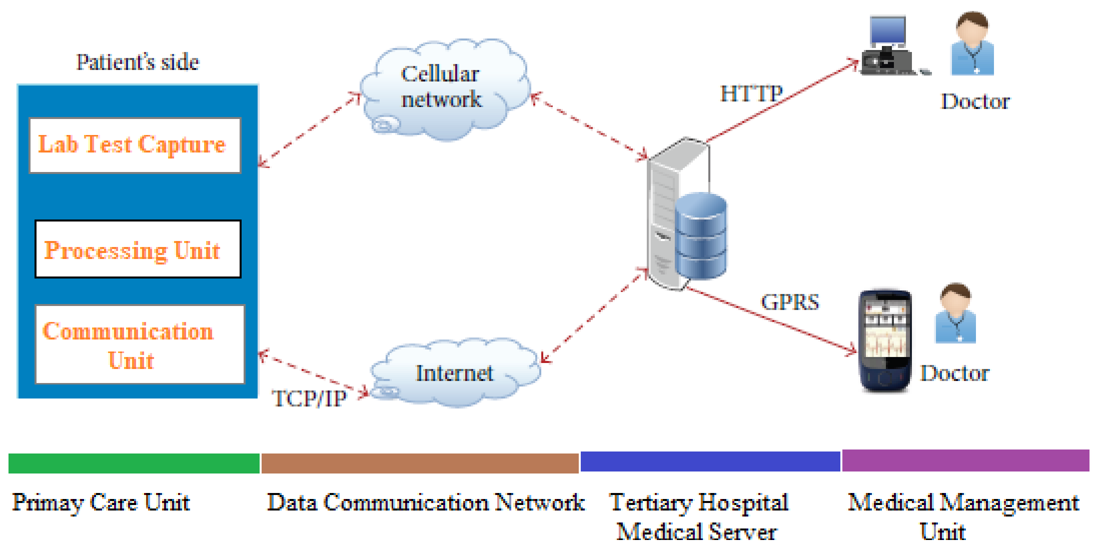

Figure 1: System design of COSETS Telemedicine System

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To boost the efficiency and physician's mobility at the tertiary hospital medical center, the global mobile communication network (GSM) was used to connect the server[15]. The Lab Test Capture unit consisted of a biosignal sensor, an A / D converter, and a storage unit in several preceding telemedicine systems. The proposed system also has a friendly web-based interface for medical staff to detect immediate symptoms of critical remote care which will allow medical staff more mobility. In telemedicine the applications for patient monitoring and diagnosis is considered backbone of the system.

The initial aim of the COSETS was to create a telemedicine system that would allow the remote healthcare centers to access the specialized medical professional available at the tertiary hospitals[16]. By enabling the exchange of knowledge across hospital sites, COSETS was designed to help resolve this gap. It is accomplished by simultaneously transmitting patient's symptom, diagnosis report and images from a medical system, camera video images and audio over a high bandwidth network link between two locations[17]. The COSETS system is easy to use, flexible, and robust and can receive multiple images at any time and send multiple two moving images or video streams.

2. Using an action research approach to design and implement a Telemedicine system

Behind the approach of Action Research is the researcher's desire to impact a significant improvement on the situation in which the research takes place when performing the research concurrently, and a collaborative approach between the researcher and the subject in achieving this aim and gaining understanding[18]. Action research is an approach in which the action researcher and subject collaborate in the diagnosis of the problem and in the development of a solution based on the diagnosis[19]. In this research method, researcher and participants from the organization or society join hands in order to solve the problem of the society. The action research is a participatory study consisting of spiral of self-reflective cycles with planning, acting, observing, and reflecting[20].

In healthcare settings, action research is the effort to 'learn through doing' with the involvement of key stakeholders, including the patient. An approach to action research is

[15] R. Sukanesh, P. Gautham, P. T. Arunmozhivarman, S. P. Rajan, and S. Vijayprasath, "Cellular phone based biomedical system for health care," in Proceedings of the IEEE International Conference on Communication Control and Computing Technologies (ICCCCT '10), pp. 550–553, Ramanathapuram, India, October 2010.
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particularly relevant in the treatment of patients and healthcare needs[21]. This inclusion is itself a cycle of social learning and is key to achieving the improved results. Action research in healthcare is a transformative approach that continuously innovates in healthcare to improve patient experiences and health of the population, reduce the healthcare cost, and improve the experience of healthcare providers[22]. Action Research aims to contribute both to the practical concerns of people in an immediate problematic situation and to further the goals of social science simultaneously[23].

The process of action research is cyclical and consists of five elements. Initially, a problem is identified and data is collected for a more detailed diagnosis. This is followed by a collective postulation of several possible solutions, from which a single plan of action emerges and is implemented. Data on the results of the intervention are collected and analyzed, and the findings are interpreted in light of how successful the action has been. At this point, the problem is re-assessed and the process begins another cycle. This process continues until the problem is resolved[24]. The various action research models found in literature are Action Research Circle[25], Action Research Process[26], Action Research Cycle[27], The Action Research Spiral[28], Spiral of Action Research Cycles[29], and Seven Phase Action Research Model[30]. From the various action research methodologies available, Spiral Action Research Cycle[31] was selected for the project. In this action research model, action research is conducted as a collaborative partnership between the researcher and practitioner. The cycle of "diagnosing", "planning", "taking action" and "evaluating action" are repeated till the output is achieved.

The use of action research in telemedicine research is an iterative method involving user needs clarity, potential approaches, and practical trials involving participants. When put into action, systematic evaluation will then continue. The phases of action research cycle include:

1. Analyzing the needs of users: Actively engaging the participants to identify particular needs and to evaluate them. Identify the key healthcare services for telemedicine in primary care and specialty care settings. The analysis examines facets of health needs and the characteristics of

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[28] Kemmis, S. and R. McTaggart. 1988. The Action Research Planner. Victoria, Australia: Deakin University Press
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[31] Right there

healthcare services to those needs. This information will provide resources to develop the information technology infrastructure to establish the communication between the outpatient primary care clinics and specialists care providers.

2. Planning the solution: Collaborative process to generate ideas and planning the solution of the issues identified during diagnosis phase. The planning phase involved finding the telemedicine solution to the healthcare access and medical facility shortage problem in remote and suburban primary care hospitals, establishing the collaboration, and preparing an action plan for implementing the telemedicine solution.

3. Implementation of action plan**:** process involving development of prototypes and implementation of the telemedicine solution. The implementation of telemedicine includes the preparation, management, design, development and coordination of the tool within the public health system. Telemedicine implementation involves service development stage which includes internal explanatory factors such as legal, regulatory, technological infrastructure, human resources, and financials for telemedicine usage by healthcare organizations. The technological infrastructure for the implementation of the telemedicine encompasses ICT infrastructure, eHealth infrastructure, and technological usability of the service.

4. Evaluating action: The evaluation phase involved the analysis of the data collected during the action phase including clinical effectiveness, security, and cost-effectiveness. Telemedicine evaluation considers the outcome factors to be measured, such as quality of treatment, acceptability, accessibility and cost. Telemedicine evaluation includes a comparison of outcome between the modern telemedicine and usual healthcare service. The primary data collection method used in this project was participant observation supplemented with group discussions and interviews.

The evaluation phase was the systematic operation of the COSETS project outcome evaluation and was also an important part of the action research approach adopted. The clinical involvement at outpatient clinics provided a wealth of qualitative and realistic knowledge that informed and fostered project success. During the initial days of the telemedicine implementation, COSETS was used for exchanging pathological information provided by pathologist of primary care hospitals, and many times ECG reports for specialist clinician validation. The use of COSETS for diagnostic purposes and the relatively low usage rate for echocardiography was expected based on findings and interviews from the evaluation phase of action research study. Although this section discusses only a small range of results from the longitudinal report, it also offers clear examples of how COSETS telemedicine system was applied by the action research approach for diagnostics of patients at primary care center.

3. Application of Telemedicine system to mitigate diagnosis shortage and spread of COVID-19

The COVID-19 has been found to have higher transmissibility rates and pandemic risk and is estimated to be higher than previously reported coronaviruses[32]. Various COVID-19 studies have estimated the essential spectrum of reproductions to be from 2 to 11 days. The WHO authorities' new guidelines indicated an average incubation period of 7 days, ranging from 2 to 14 days[33]. The most frequently reported symptoms are fever, cough, myalgia or tiredness, pneumonia and complicated dyspnea, while the less frequently recorded symptoms include headache, nausea, hemoptysis, runny nose and cough[34]. The following screening procedures have been recommended for patients with suspected infection: Carrying out real-time fluorescence (RT-PCR) to detect the positive nucleic acid of SARS-CoV-2 in sputum, throat swabs, and secretions of the lower respiratory tract samples[35].

Studies suggested that COVID-19 spread was fairly fast and reported spreading to many other countries after its outbreak in China. No specific antiviral treatment has proved successful so far against COVID-19; Medical institutes may take isolation treatment and observation protocols to prevent and monitor COVID-19 spread[36]. The National Health Commission[37] has released recommendations for rapid prevention and control measures to effectively control the spread of the disease through a “big isolation and big disinfection”. Social distancing[38] strategies found to effectively mitigate the local progression of pandemic diseases without the use of vaccine or antiviral drugs. This section describes in detail the system design based on mobile application and COSETS telemedicine system to implement social distancing and reduce diagnosis shortage. Figure 2 illustrates the architecture of the proposed system.

The aim of this study was to design and implement COSETS telemedicine system with mobile application for COVID-19 symptom monitoring and patient diagnosis at primary

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healthcare centers. The architecture of the proposed system was shown in Figure 2. The system mainly comprise of two parts: Mobile application and COSETS telemedicine system.

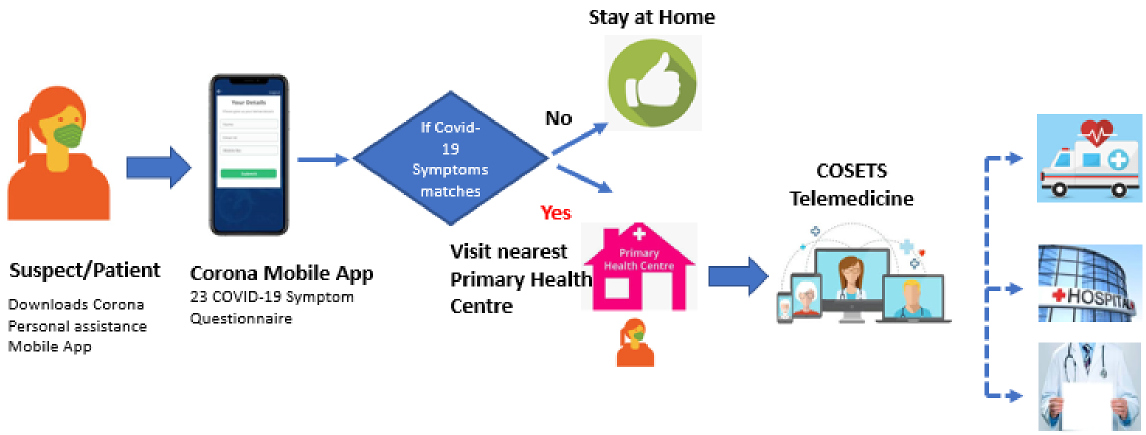

Figure 2: The architecture of the proposed system

- Personal Assistance Mobile Application: The mobile application was developed using the symptoms and testing assessment tools[39] for COVID-19. This is a questionnaire-based classification for suspected COVID-19 patients using an artificial intelligence (AI) based algorithm. The AI algorithm classifies the suspected patients into mild, moderate or severe. The application was developed using the rapid application development (RAD) process[40]. Using this software development methodology, the processes of development are divided into three main phases: prototyping, development, and deployment. Upon completing all the development steps, the software was then uploaded to the Play Store. When the personal assistance mobile application was released in the Play Store, users could download it and install it on mobile phone. The application was designed to save electronic health record data with storage space in the cloud database. Therefore, questionnaire data and user's response input into the system is available to primary healthcare center and specialists at tertiary hospital.

The mobile application acquires information of vital signs in real time or regularly without impacting their daily activities. Then an AI data analysis algorithm is implemented to detect COVID-19 symptoms and transmits these data to the remote cloud server via wireless communication through either internet or store-and-forward mode cellular networks. If the user vital signs matches COVID-19 symptom, he is directed to the nearest primary care center with the use of locating system such as global positioning system (GPS), the geographical information system (GIS), and artificial intelligence system for first level of COVID-19 guidance or check-up.

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[39] World Health Organization, Clinical Management of Severe Acute Respiratory Infection when Novel Coronavirus (nCoV) Infection Is Suspected: Interim Guidance, (2020) https://www.who.int/docs/default-source/coronaviruse/clinicalmanagement-of-novel-cov.pdf.
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The personal assistance mobile application was deemed to have achieved the development objective of social distancing allowing users for initial screening remotely with no travel to primary healthcare centers or tertiary hospitals. Figure 3 shows example screenshots for personal assistance mobile application.

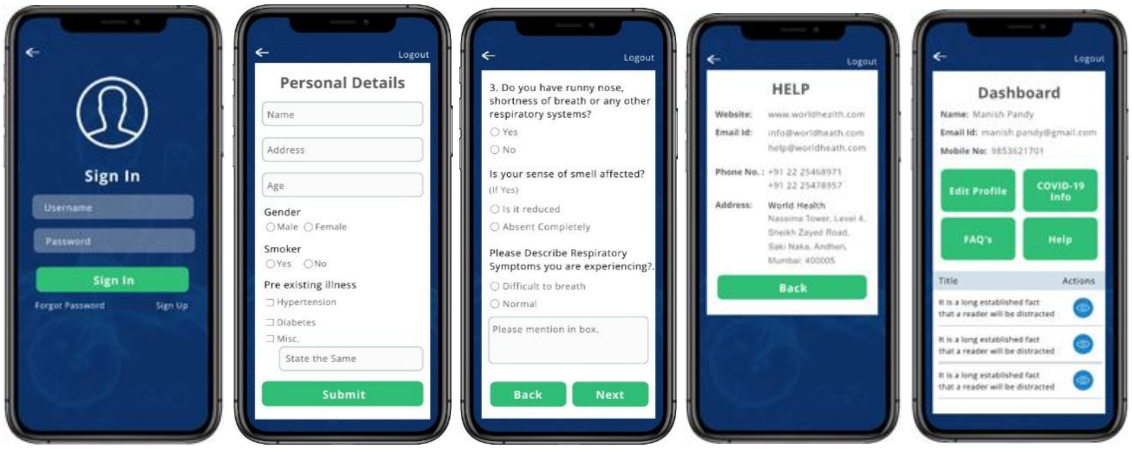

Figure 3: Exemplar of COVID-19 assessment tool screenshots

- COSETS telemedicine integration with Mobile Application: The Personal Assistance Mobile Application shared the healthcare information with COSETS telemedicine through design of an integrated database hosted on cloud platform. An integrated database is a database that serves as a data store for multiple applications, thus ensuring data integrity between applications[41]. The benefit of exchanging data between applications is that it does not require an extra layer of integration services for applications. Any changes to the data performed on an application will change all the data in other applications automatically so that synchronization is easy. The integrated database incorporates information from more than one data source.

The integrated COSETS telemedicine system consists mainly of two modules. Primary care unit and Tertiary hospital module. The primary care unit can collect preliminary diagnosis data including ECG, blood pressure, pneumonia and SpO2 which are vital signs for COVID-19. It may process the acquired diagnosis data to determine whether or not their respective values are above the preset limit. If any or more of these values surpass their respective critical values of COVID-19 infection then the alarm is triggered. After that all processed data are transmitted via GSM/GPRS network in real-time to the Tertiary hospital module.

In telemedicine, medical information generally needs to be distributed among doctors and display, archiving, and analytical devices. The tertiary hospital module is therefore built with the intention of receiving, storing and transmitting patient vital sign data. The tertiary hospital enables different users, such as physicians, surgeons and medical centers to communicate with the server

[41] Filis I V, Sabrakos M, Yialouris C P, Sideridis A B and Mahaman B 2003 GEDAS: an integrated geographical expert database system Expert Systems with Applications 24 (1) pp 25-34

through a web interface. The users at tertiary hospital shall be able to view vital signs of COVID-19 patients via the internet in real time and continuously to perform RT-PCR IgM/IgG diagnosis of the patients referred to Tertiary hospitals. The module is designed to allow tertiary hospital users to acquire critical diagnosis information anywhere and at any time using devices such as laptops, PDAs, and cell phones. The preliminary diagnosis test conducted at primary health care centers reduce the workload at tertiary hospitals. The patients only requiring COVID-19 diagnosis are sent to tertiary hospitals therefore reduce the growing shortage of diagnosis facility in India.

Conclusion

The novel coronavirus originated from Wuhan, China rapidly spread up to 199 countries and territories around the world. No promising vaccine or treatments against COVID-19 have been established thus far. However, researchers suggest that targeted social distancing techniques can be developed to reduce local pandemic COVID-19 development effectively without the use of vaccinations or antivirals. Although, implementing social distancing is a challenge. Through this study, it was found that how personal assistance mobile application contributed to designing and implementing social distancing for complex COVID-19 that is useful.

This study explored how an action research approach could affect COSETS's success. Action research offers participants an opportunity to recognize specific issues and build and validate technologies. The action research cycle includes identifying needs, planning, taking action and evaluation. In this study, action research methodology has helped implement COSETS telemedicine system and distribute the diagnosis associated with COVID-19 and encouraged suspected patients to visit tertiary hospitals for detection of SARS-Cov-2 after conducting preliminary diagnosis at primary care center.

Recommendation

This paper suggests the design and implementation of a telemedicine system integrated with personal assistant mobile application to manage the possible spread of the pandemic. The study recommends to capture the COVID-19 clinical symptoms through the mobile application and are transmitted to primary care center module of telemedicine system in suspect case. By this, travel to primary care or tertiary hospital is reduced significantly as only suspect cases will be transmitted to primary care center. It is also recommended that suspect patients undergo preliminary diagnosis at primary care center preventing the increased crowd at the tertiary hospitals.

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