Original Article

Development of Mobile Application-Based System for Improving Medication Adherence Among Cancer Patients Receiving Palliative Therapy

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ABSTRACT

Objectives: Cancer patients seeking palliative care faces distressing symptoms which affect their quality of life adversely. Patients' lack of adherence to analgesics is one of the major factors contributing to the undertreatment of cancer pain. The objective of this paper is to outline the development of a mobile application-based system to develop a physician-patient relationship and to improve adherence to medications prescribed for cancer pain management.

Material and Methods: The mobile application-based system is developed using alarm and cloud based data sysncronisation for improving medication adherence and self-recording symptoms among cancer patients receiving palliative therapy at a palliative care clinic.

Results: Ten palliative medicine physicians tested the project website and the mobile application thoroughly instead of patients. The physician recoded the prescription and other details on the project website. The data transferred from website to mobile application. The mobile application reminded scheduled medication by alarm, collected medical adherence details, daily symptom observation, and their severity and SOS medication details. The data from the mobile application was transferred back to project website successfully.

Conclusion: The developed system can directly improve the physician-patient relationship, and improve better communication and sharing of information between physician and patient. This will impact the quality of life of the patient, improve the awareness of the patient about the disease, and may reduce rate of hospitalisation. This will also help physicians to treat patients efficiently. The developed system is being tested under a randomised control trial study. The findings of the study can be generalised to all patients suffering from chronic illnesses and on long-term medications.

Keywords: Mobile application, Analgesics, Cancer, Symptom management, Drug adherence, Palliative care

INTRODUCTION

Cancer is one of the leading causes of morbidity and mortality worldwide. Based on the GLOBOCAN 2020 estimates of incidence, mortality, and prevalence of the cancer burden worldwide and cancer fact sheets, there is an estimate 19.2 million new cancer cases and 9.9 million cancer deaths in the world in 2020.[1] India also reports an increase in the trend of cancer incidence varying from 548,000 in 1990 to 1,069,000 in 2016.[2] Cancer patients have symptoms due to the disease itself or related to therapy and affect the quality

of life adversely.[3] Pain, constipation, nausea, and vomiting are significant distressing symptoms reported by cancer patients.[4] Palliative care is the care provided by specialised health-care professionals for relieving various symptoms for the management of total suffering and thus improving the quality of life of patients with chronic diseases.[5] The symptoms are managed using a multimodal approach including pharmacological and non-pharmacological measures.[6] Patient perspectives such as beliefs in health and illness, motivation, prescriber-patient relationship and permitting autonomy significantly influence medication

adherence in patients with chronic disease conditions.[7] Patients' lack of adherence to analgesics is one of the major factors contributing to the undertreatment of cancer pain.[8] Non-compliance to prescribed around-the-clock analgesics builds up hospitalisation rates of cancer outpatients, mounting the economic burden of developing countries like India.[2,3]

Mobile technology is revolutionising the contemporary health sector through mobile health apps.[9-13] Smartphone apps are cost-effective and help in tracking and recording data about health, making health care more accessible to outpatients. The use of mobile applications has improved clinical decisions and patient care.[13,14] It appears that the use of smartphone mobile applications shall be useful to improve drug adherence in advanced cancer patients receiving palliative care. Evidence shows that mobile app-based interventions are accessible, acceptable, cost-effective and a novel approach to enhance medication compliance, symptom recording, and management in patients with chronic illness. Thus, a mobile application-based system is envisaged to track patients' health information, medication plan, reminders and monitoring of other symptoms, to enhance medication adherence and improve the quality of life of cancer patients.

The objective of this paper is to outline the development of a mobile application-based system to support advanced cancer patients in improving adherence to medications prescribed for cancer pain management.

MATERIAL AND METHODS

Development steps of the smartphone-based mobile application system

The smartphone-based mobile application system is developed by designing a server system, a project website, a mobile application, and synchronisation system between the project website and mobile application using the internet. The various components and steps of the system development include [Figure 1]:

Development of web server and database server

Linux operating system (OS) with Apache web server is an open-source platform and provides all the features required for professional web designing. MySQL is an open-source database and requires its installation on the server. The web server system is protected from direct public access by routing access through a reverse proxy server and a firewall system wherein security policies are implemented.

Development of project website

The project website is designed using PHP, scripting languages, and advanced features of the website. PHP is used as it is a server-side scripting language with faster execution, better security options, and compatibility with the Apache server. The project website is designed with the following features:

Registration for physicians

This webpage is designed to record the details of physicians associated with the project and provide them access to patient information.

Registration for patients with advanced cancer and seeking palliative care

This webpage is designed to record the details of patients with advanced cancer, visiting a palliative care clinic. The project website is designed to provide a unique id to all registered patients.

Registration for medicines

This webpage is designed to record the details of all the medicines including dose, frequency, and SOS (as and when needed) doses, prescribed by palliative care physicians.
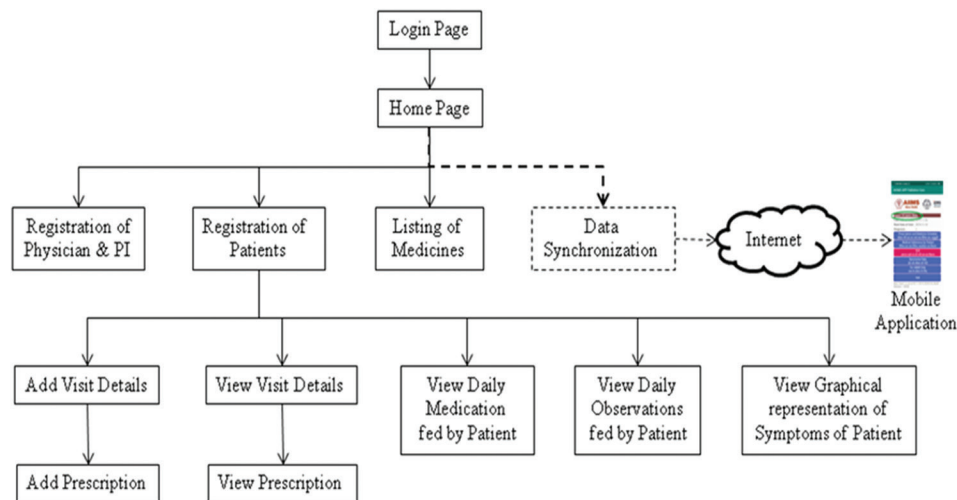

Figure 1: Data flow diagram of project website.

Webpage to record medication prescription

This webpage is designed to facilitate physicians to record the medication prescription, schedule the timing for taking regular medicines, prescribe SOS medicines, and assign the next date of visit for the patient.

Webpage for recording demographic profile

The web page is designed to record the sociodemographic profile of participants. It includes age, gender, type of family, area of residence, state of residence, marital status, patient relationship with the head of the family, education, occupation, monthly income of the family, socioeconomic status, distance of residence from the treating hospital, mode of commuting to hospital and health insurance. Socioeconomic status is designed to assess status using the Modified Kuppuswamy scale updated for the year 2018.[15]

Webpage for recording clinical profile

The web page is designed to record clinical and adherence status to the prescribed regimen. It includes clinical diagnosis, stage of cancer, duration of illness, associated comorbidity, duration of analgesics, and prescribed analgesic treatment regimen which consists of physician-prescribed and patient-reported dose and frequency of analgesics. Analgesics are categorised into opioids, non-opioids, adjuvant analgesics and adjuvants such as laxatives, anti-ulcer agents, and antiemetics.

Webpage to automate date-wise scheduling of medication

Based on the prescription, schedule of medicines, and assigned next date of visit, a webpage is designed to automatically prepare a date-wise schedule for medications from the date of visit to the next scheduled visit in respect of the patient.

Application programming interface (API) to transfer data from the project website to the project mobile application

An API is designed to transfer the patient detail, medication details prescribed by a physician, and the date-wise and time-wise schedule to Mobile Application in an encrypted format.

API to receive data from the project mobile application and save it on the project website

Another API is designed to receive the date-wise and time-wise details of medication taken by the patient, the problems faced by the patient throughout the day, and details of SOS medicines taken by the patient through the Project Mobile Application installed in the smartphone of the patient.

Webpages to display the information recorded on the project website

Webpages are designed to display the following information:
- Details of registered physicians
- Details of registered patients with advanced cancer
- Details of visits of the patient at the palliative care clinic
- Details of medication prescribed by the physician
- Details of medication taken by the patient
- Details of the symptoms recorded by the patient during his/her medication period at home through the project mobile application
- Details of SOS medicines taken by patient during his/her medication period at home through project mobile application.

Development of mobile application

As per the StatcounterGlobalStats website, about 96% of mobile phones in India are based on Android OS;[16] thus, an Android OS-based mobile application is selected for designing the project mobile application. The Android OS version 4.0 was launched in 2011. Thus, the project mobile application is developed using Android Studio which can run on any Android device with OS 4.0 or above having at least a 4' screen size. The SQLite database is used for recording data in the mobile application. The mobile application is designed considering its installation in the smartphone of the patients. The interface of mobile application is designed with a user-friendly interface so that even an unskilled patient can operate it. The complete data flow diagram of the mobile application is shown in [Figure 2]. The details of the features designed in the project mobile application are as follows:

Registration of mobile application

During the 1st-time installation, the mobile applicationis designed to ask for the unique id of the patient and password for linking the mobile application with the project website. The credentials submitted by the mobile application are verified by the project website through the internet and an acknowledge message is sent by the project website. The credentials are recorded in the mobile application database and the registration process gets completed.

Synchronisation of patient information from project website to mobile application

After successful registration of patient credentials in the mobile application,the details of the patient are transferred from the project website to the mobile application and recorded in the mobile application database

Synchronisation of patient medication information from project website to mobile application

The medication synchronisation process is executed, wherein the details of medication prescribed by the physician, details of regular medicines and SOS medicines, date-wise and time-wise schedule of medicines and next date of visit assigned by the physician are transferred from the project website to mobile application.
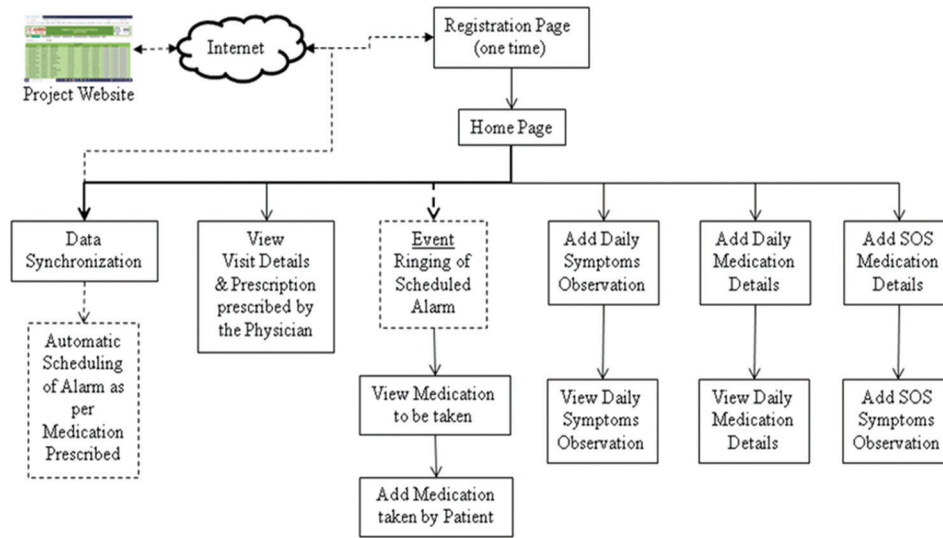
Figure 2: Flow diagram of mobile application.

Automatic setup of alarm as per schedule of medication in mobile phone

Mobile application is designed to set up alarms using the default alarm system of mobile phones, based on the date-wise and time-wise schedule of medicines.

Additional processes executed during the playing of alarm

The mobile application is designed to play alarm at the time of scheduled medication and display the list of medicines, along with the prescribed dose to be taken. The console page is designed to get the details of the dose of medicine taken by the patient.

Home page of the App

The home page of the mobile application is designed wherein the patient can view the details of the advised prescription and the schedule of the medication.

Page to record daily drug adherence details

A 'Daily Drug Adherence' button is provided on the Home Page. By pressing this button, the mobile application displays the list of all the medicines along with the scheduled time and prescribed dose to be taken. If the patient has recorded the dose during the playing of the alarm, the console displays the recorded information. Here, the patient is given the option to record the dose taken if he has missed recording it during the playing of the alarm.

Page to record daily observation details

A 'Daily Observation' button is provided on the home page of the mobile application. By pressing this button, the mobile application displays the list of symptoms such as pain, nausea, vomiting, and constipation scored on corresponding objective rating scales during the day. This page enables the patients to self-record their symptoms. It enhances patients' self-efficacy in managing the side effects of analgesics.

The rating scale in the 'Daily Observation' option is designed based on the standardised scale of adherence to refills and medication scale used to assess medication adherence of chronically diseased patients with a low level of literacy.[17] It comprises 14 items that assess adherence to refill prescriptions and adherence to medication consumption. Each item is structured for the response on a Likert scale with responses of 'none', 'some', 'most', or 'all' of the time, which are given scores from 1 to 4. A lower score on the scale indicated better adherence.

The descriptive rating scale in the 'Daily Observation' option was designed to measure subjective reporting of symptoms which are believed to range across a continuum of values. Five descriptors: 'none', 'mild', 'moderate', 'severe' and 'very severe' with scoring from 0 to 4, respectively, are used to rate the worst pain, nausea/vomiting and constipation experienced by patients in the past 24 h.

Page to record SOS details

In case of pain or any other symptom, the patient is advised to take medicines prescribed as 'SOS' by the physician. On the home page of the App, an 'SOS' button is provided. If the patient presses the 'SOS' button, the mobile application displays the list of medicines prescribed as SOS by the Doctor. The patient can record the dose of SOS medicine taken by him, the time of taking medicine and the symptom faced by him.

Other pages on mobile application

The patient can view
- Prescription prescribed by Doctor
- Details of drug adherence
- Symptoms recorded by himself.

Synchronisation of patient medication information from a mobile application to a project website

The mobile application is designed to work offline. At any desired time, the patient can press the 'Syncronize' button in the mobile application to transfer data from the mobile to project website and *vice versa* using the internet. When the 'Syncronize' button is pressed, the details of drug adherence, SOS medicine is taken by the patient, daily observations and symptoms recorded by the patient are uploaded from the mobile application to the project website through the internet. This enables physicians to monitor the status of medication adherence and symptoms of the patient remotely and anytime by exploring the project website.

Data security and patient privacy

The project website is protected using a reverse proxy server and a firewall system. Security policies are designed so that a public user cannot reach project databases and website scripts. JavaScript Object Notation encryption is used during the transfer of information from the website to the mobile application and *vice versa*. The details of patients are made visible to concerned physicians only. The mobile application cannot be activated unless authorised credentials are provided to the mobile application. One patient cannot view the details of other patients.

System testing and validation

The palliative medicine physicians at the palliative care clinic of a tertiary care institute were given training about the working of the developed system. These physicians were registered on the project website and assigned credentials to log in. Physicians added the list of all the medicines being used for the treatment of cancer patients on the website. Physicians recorded the dummy date of the visit of all the patients, recorded diagnostic remarks, prescribed medicines, their doses and scheduled the time for the dose to be taken by the patient. The physicians also recorded the details of medicines such as SOS which can be taken in case of uncontrolled pains or other symptoms. Physicians checked the schedule prepared by the website thoroughly.

During the development of the mobile application, it was observed that most of the patients or their family members were having Android based smartphones with a minimum 4 inches screen size. Thus, a mobile application was developed for 4 inch screen and tested on different versions of Android. The APK file of the final mobile application is shared through the project website.

Ten palliative medicine residents were registered as a patient on the project website. The mobile application is downloaded from the project website to their mobile phones. As designed, the application is registered with the patient id provided by the project website and password. The patient information, prescribed medicines, their doses, schedule of medicines, and SOS medicines details are transferred from project website to mobile application through the internet automatically after registration. The mobile application then automatically setup the alarm as per the schedule of medicine.

RESULTS AND DISCUSSION

After the successful installation of the mobile application, the physician and medical residents thoroughly cross-checked the working of the project website and mobile application. The residents confirmed that the mobile application alarmed timely and reminded them to take the prescribed medicine. The medical residents studied the mobile application from the point of view of the patients and recorded the dummy details of the dose taken. The residents also recorded the details of daily symptom observation, symptoms severity on the prescribed scale and medication details considering themselves as the patient. The residents validated the alarm system, details updated by them and the feature of SOS medicine. They transferred the details from mobile application to project website using the 'Synchronisation' button of the mobile application. The residents also tested the working of mobile applications after restarting the mobile phones. They tested the functioning online as well as in offline mode.

The project website successfully received the data from mobile applications through the internet. The physicians studied and cross-checked the details of medication updated by the residents as the patient, the daily symptoms faced by the patient, SOS medicines taken by the patient, and the severity of symptoms recorded by the patient. The project website displayed a graphical representation of the symptoms faced by the patient. The complete system worked successfully and efficiently.

In a study in America, a mobile application was developed to record the daily symptoms and their severity faced by ten cancer patients.[18] A review study reviewed about 160 mobile applications for medical adherence and observed that many apps are designed to record medical adherence and some systems have used SMS and telecommunication for reminding medicines. In these apps, patients can add their medication details and monitor their adherence.[19] Our mobile application system is specially designed for cancer patients seeking palliative care under the direct observation of their physicians. Only a physician can change the prescription and the schedule of the medication. The automatic alarm system reminds the patient and also displays the details of the medication prescribed by the physician. It allows the patient to record the dose of medication taken by him. The mobile application is designed to improve the physician-patient relationship.

CONCLUSION

The mobile application-based system is developed for cancer patients seeking palliative care and successfully

tested by the palliative medicine physicians at the pain and palliative care clinic. The developed system can directly improve the physician-patient relationship, and improve better communication and sharing of information between physician and patient. The better relationship and improved medical adherence will impact the quality of life of the patient, improve the awareness of the patient about the disease, and may reduce rate of hospitalisation. The details of the patient's compliance with the given therapy will support health-care professionals to treat the patients efficiently. The developed system is being tested under a randomised control trial study. The findings of the study can be generalised to all patients suffering from chronic illnesses and on long-term medications. This app can be modified for patients with chronic ailments, to enhance their medical adherence and quality of life.

Acknowledgements

Declaration of patient consent

Patient's consent not required as there are no patients in this study.

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Conflicts of interest

There are no conflicts of interest.

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