34th Annual International Conference of the IEEE EMBS
San Diego, California USA, 28 August - 1 September, 2012

A Mobile-Health System to Manage Chronic Obstructive Pulmonary Disease Patients at Home *

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***Abstract*— Chronic Obstructive Pulmonary Disease (COPD) is a major cause of morbidity and mortality in Australia and globally, and leads to a substantial burden on healthcare services. Effective and timely management of patients with COPD has been essential to alleviate COPD exacerbation, improve the quality of life, and consequently reduce the economic burden. To achieve this, a mobile and internet technologies assisted home care model (M-COPD) was developed to assist clinicians to remotely monitor and manage COPD conditions and events. This paper will focus on the technical aspect of M-COPD system by describing its setup and discussing how the M-COPD could address the clinical needs in monitoring and managing COPD conditions of patients at home.**

I. Introduction

Chronic Obstructive Pulmonary Disease (COPD) is a major cause of morbidity and mortality in Australia and worldwide, and imposes a great burden on the healthcare services. In 2008, two million Australians, equating to nearly 18.6% people aged 40 or over, were affected by COPD [1]. As the ageing population increases, Australians affected by COPD is projected to reach 4.5 million in 2050 [2]. The estimated direct costs associated with COPD in Australia in 2008 were $0.9 billion [2]. The costs in UK and USA were £0.8 billion in 2003 [3] and $18 billion in 2005 [4], respectively.

Management of patients with COPD at home has been emphasized to be effective and safe to improve the quality of care, alleviate the burden to crowded hospitals and emergency departments, and reduce health care costs. Studies have demonstrated that the hospital stay of patients with exacerbations, acute worsening of COPD conditions, accounts for 40–57% of the total direct cost of COPD [5,6]. A recent study [7] demonstrated that many patients with COPD can be managed effectively and safely at home. However, in practice, delivery of effective and safe clinical services to a remote home environment remains limited by the availability of clinicians to attend patient homes.

To assist home care management of COPD conditions and events, a mobile technology assisted home care model (M-COPD) was recently developed by the Australian E-Health Research Centre, CSIRO (AEHRC) to enhance the link between patients and clinicians. The system enables clinicians to remotely monitor patients' COPD conditions, diagnose exacerbations of COPD in the early stages, and treat some mild or moderate exacerbations with prescribed medications at home. Through the system, patients would receive timely assessments and treatments; and clinicians would save travel time and costs. The M-COPD model was then evaluated through a pilot trial at the Royal Perth Hospital, Perth, Western Australia.

The aim of this paper is to demonstrate the M-COPD system on the technical aspect by presenting its framework and discussing how the M-COPD system addressed three major clinical needs for delivering remote care services: i) timely assessment of patients' COPD conditions, ii) collaborative care of multi-disciplinary teams, and iii) effective analysis and management of patients' health information. It is expected that this paper can provide a useful framework for applications of innovative smart phone and internet technologies to clinical studies.

II. Architecture of M-COPD

The M-COPD model is illustrated below in Fig. 1. In the model, patients use mobile phones to update self-assessment and observation data relating to COPD symptoms and vital signs, such as sputum, wheezing, cough, heart rate, body temperature, etc. The updated data are stored in a remote server, and subsequently made available to clinicians on a web portal. Clinicians use the internet to access the portal and review the patients' information on a daily basis to assess the disease progress. Based on the clinical assessments, exacerbations of COPD can be detected at early stages, and some light and moderate exacerbations are treated with medication at home, such as use of antibiotics, bronchodilators, and corticosteroids. Some clinical interventions and educations on inhalation technique and correct use of pacer are given through mobile video calls. Nurse home-visits are still applied when it is needed, but, in comparison with the traditional nurse visit based care programs, the number of nurse visits can be dramatically reduced in the M-COPD program.

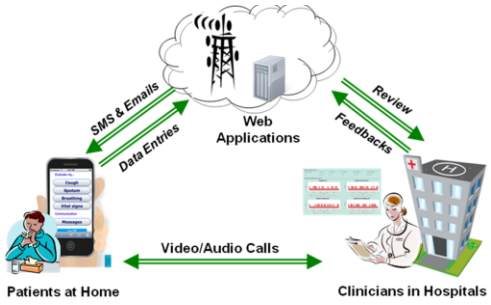

Figure 1. Home care model of M-COPD.

*Research supported by the Australian e-Health Research Centre.

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The M-COPD system integrates a series of web applications, developed in the Java language. A Tomcat server with the Container Managed Security was used to host the web applications. The architecture of M-COPD is shown in Fig 2. A generic mobile web application was developed for patients. This mobile web application does not require installing any native mobile application to patients' phones. Patients simply use widely available mobile internet browsers to log on to the web application, answer assigned questionnaires, and enter measured or observed data. A mobile email and a SMS engine are provided for patients to receive feedbacks, intervention materials, and reminders provided by clinicians.

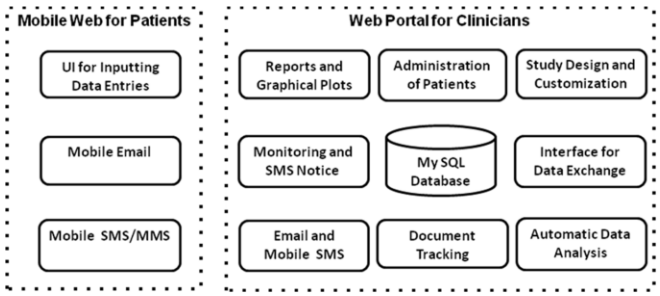


Figure 2. System Architeture of M-COPD.

Associated with the mobile web application is a web portal, which was developed for clinicians to manage, analyze and review the uploaded patients' data. As shown in Fig. 2, the portal contains the following major components.

Administration of Patients: a web based User Interface (UI) was developed for clinical administration officers to register patients, set patient status, update patients' profiles, and refer/assign corresponding healthcare professionals for individual patients. Following patient consent, they are registered on the system, SMS messages, such as a welcome message with login details, will be automatically generated and sent to the respective patients.

Reports and Graphic Plots: a number of visualization tools were developed and integrated in the system. Clinicians can select suitable tools to view and analyze patients' data according to their needs.

Email and Mobile SMS: a web component was designed to automatically send scheduled SMS messages to patients. Clinicians can also use this application to send feedback messages, alerts, appointments, and education material to individual patients.

Monitoring and SMS notices: This application monitors the completion of data entries and sends SMS reminders if required data are not uploaded on time.

Automatic data analysis: This component is developed to monitor progress patterns or trends. If abnormal trends are detected, the system will automatically report results to clinicians for further diagnosis.

Study Design and Customization: This function is used to assign entry variables, schedule mobile SMS messages, design education materials, and setup visualization tools.

Document Tracking: a web application was developed to track assessment and questionnaire forms scheduled at different assessment stages.

Interface of Data Exchange: This component is to exchange data between the M-COPD system and other healthcare application systems. Therefore patients' data can be shared by other healthcare services.

III. Evaluations and Functionalities

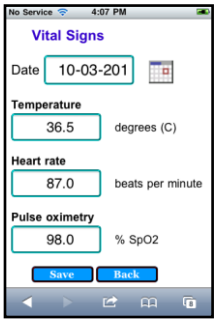
The M-COPD system was implemented in a pilot clinical study at the Royal Perth Hospital in Western Australia. In the trial, ten COPD patients were recruited. Each patient was given a mobile phone (iPhone 4, and a set of care protocol). Consenting patients underwent the trial for a three month period. The evaluation of the patient's conditions is tracked daily for their severities and timely attendance is provided by telephone consultation should their conditions need alterations to medication or advice. One major objective of trial is to evaluate the usability and feasibility of using the M-COPD system for the clinical study. The ethics approval for the trial was obtained from the Human Research Ethnics Committees in Western Australia [8].

The M-COPD provides a simple UI for patients to manually input observed and measured clinical data. Some selected UIs of the web application for patients are displayed in Fig. 3. As mentioned above, patients use web browsers of mobile phones to log into a web application, specifically customized for mobile phones (Fig. 3a). Once patients log in, a main dialog (Fig. 3b) appears. From it, patients select the options of entering measured vital signs data or observed COPD symptoms including cough, sputum, and breathing. A mobile email is provided at the bottom of the dialog for patients to view feedbacks and education materials sent by their clinicians.

a

b

c



d

Figure 3. User Interfaces of the web application for patients. (a) Dialog of login. (b) Dialog of options for various data entires and mobile email. (c) Dialog of cough assessment. (d) Dialog to enter vital signs.

The observed symptoms are automatically related into scores according to formal clinical classifications, for the clinicians to make their clinical assessments. For example, frequency of cough in M-COPD is classified into four levels (Fig. 3c). The descriptions of the cough classifications are given as selection options. By simply selecting an option, cough symptom is classified and scored. A set of thermometer and pulse oximetry device is provided to each patient. Patients use the devices to measure body temperature, heart rate and pulse oximetry, and upload their measured values through the mobile phone shown in Fig. 3d.

Uploaded data entries are stored in a database on a server, and made available for clinicians to analyze and review the health status and progress of the COPD of individual patients. Through the administration process, each clinician is also provided a set of user name and password to log onto the web portal. Through the portal, a clinician can manage his/her patients and review the patients' data. Fig. 4 shows an example of the graphic plots of patient data viewed by the clinicians. By reviewing the plots, the changes of symptoms over the last fortnight can be observed; and fluctuations of the temperature, heart rate and pulse oximetry can also be viewed.

Figure 4. UI of the web portal for clinicians to review patients' health status and CODP conditions.

IV. DISCUSSION

Obtaining health and medical information of patients is paramount for clinicians to provide care remotely to patients at home and deliver effective and safe clinical interventions and treatments, which can be limited in the traditional nurse-visit programs. In the M-COPD program, patients' health and medical information is transferred to clinicians or nurses through patients' mobile phones, and made available for clinicians to review, virtually, in real time. Such care programs would potentially result in large savings of travel times and costs compared with nurses who would make visits to patient homes and, hence prioritize their care towards more regular monitoring and analyzing patient's disease progresses and providing individualized interventions, accordingly. The developed generic mobile web application does not require installing any native mobile application relying on a mobile infrastructure, and hence, its accessibility by patients is not limited to smart mobile phones, but can also be accessed by normal tablet PCs and desktop computers with internet capability. Standardizations of mobile internet protocols and languages, such as HTML 5 and Java scripts, are increasingly improving the compatibility and functionalities of mobile web applications. The National Broadband network [9] with extensive internet and mobile coverage and high communication data rates will dramatically enhance the fundamental infrastructure, and accommodate wide applications of innovative mobile telecommunication and internet technologies to improve the healthcare outcomes.

Linking multi- professional collaborative teams to deliver home care services is essential to ensure quality of care, and is challenging in traditionally home care programs. The M-COPD system provides a centralized platform with designated functions to assist collaborative care services. For example, the centralized system can simplify patient referral and administration process, and improve accessibility to various healthcare professionals. Additionally, patients' health information can be easily shared through internet and made available to a large range of clinicians regardless of their geographic locations. These features will improve the accessibility and collaboration of multi-disciplinary teams through the program.

Application of the M-COPD has a great potential to improve the diagnosis and treatment of exacerbations frequently presented by COPD patients, by timely interventions. Moreover, advanced visualization tools can be applied to detect the changes of the conditions and progresses of COPD. Some rule based monitoring mechanisms can be implemented to help clinicians or nurses monitor the COPD symptoms. For example, the symptoms can be quantified and monitored in real time. If the change of symptoms is statistically significant or moves above assigned threshold levels of criticality, corresponding alerts will be generated and sent to clinicians or nurses automatically. Through the M-COPD, rich source of new set of patient data can be easily gathered to see longitudinal progressions of the disease. This could lay care protocols that improve the sensitivity to assess or detect subtle changes in COPD symptoms. The information can also provide inputs to design individualized care plans, and optimize their effectiveness through their care program. It is expected that the availability of extensive and timely health information can help detect exacerbations of COPD at early stages. This will lead to early interventions to address and prevent the deterioration of the COPD condition and hence, improve the quality of life.

The potential of using mobile devices to improve clinical outcomes in healthcare has been recognized. This is being driven by the growing popularity and rapid advances of mobile technologies. The total number of mobile phones surpassed the number of fixed telephone lines in 2002 [10].

Mobile devices nowadays are of high computing power, high storage capacity, and broadband internet connectivity, which are comparable to those of normal computers. A study of the World Health Organization (WHO) has reported certain high levels of mobile telemedicine activity among their member states in European (64%) and Americas (75%) regions [11]. In Australia, the National E-Health Tansition Authority has demonstrated a mobile application to help patients access their health records [12]. Similarly, applications of mobile technologies in health related field are being proposed by some major mobile network providers such as Telstra [13] and Vodafone [14]. Although these present a progressive future for mobile health, the effective merging of the mobile and internet technologies in healthcare systems to address clinical needs remains unclear and under research. Additionally, issues of usability, security, and interoperability [15] still exist.

V. SUMMARY

The quality of life of patients with COPD is significantly reduced and this imposes a large burden on the healthcare systems. This paper is focused describing the technical aspect of M-COPD program to demonstrate a mobile phone based solutions delivering remote monitoring and care to COPD patients at home. The M-COPD program has a great potential to improve collaboration of multi-disciplinary teams in the care program, and assist them in analyzing and diagnosing acute COPD conditions. It is expected that the application of M-COPD will lead to improved clinical outcomes in terms of early detections of exacerbations, slowed deteriorations of COPD, and improved quality of life. Hence, successful implementations of such a home care model may have the capacity to reduce the burden of COPD and reduce overcrowding emergency departments, faced by many hospitals. Applications of innovative mobile and internet technologies are still new to healthcare systems, and clinical guidelines on these applications are limited. While the pilot trial of the M-COPD program is currently in place and may demonstrate outcomes, large clinical trials evaluating clinical outcomes and cost efficiency are necessary to lead to the final adoption of the M-COPD care model in practice.

ACKNOWLEDGMENT

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. It was funded by the Australian eHealth Research Centre in collaboration with the Royal Perth Hospital, Perth, Western Australia.

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