RESEARCH NOTE

A Prototype of Simple and Low-Cost Medication Support System for Outpatient under Long-Term Treatment

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Abstract This paper presents an implementation of simple and low-cost medication support system for outpatient of cerebral infarction who has to keep medication every day for long term. The system consists of the outpatient and the pharmacist terminals at the dispensing-pharmacy. The outpatient terminal features the displays of compliance status and 3D simulation of cerebral infarction, contact functions to dispensing-pharmacy (e.g. call, text and voice messages). The pharmacist terminal features response functions to contacts from the outpatients, displays of the compliance status and the 3D simulation of cerebral infarction same as the outpatient terminal. The compliance status of the outpatients is automatically transmitted to the pharmacist terminal through e-mail connections each day. We designed different symptoms of the blood flow simulation according to the blood-stuck level which are estimated by weighted moving average of the daily compliance status (“took medicine” or “did not take medicine”). The different symptoms of 3D simulation are also registered in the database on the outpatient and the pharmacist terminals, respectively, and are switched according to the shared compliance status. Conventional medication support system used MySQL database engine on web server for those features and thus needed to introduce web server in dispensing-pharmacy. The proposed system realizes simple and low-cost by making the database of those compliance status data using the SQLite database engine on the terminals.

Keywords: compliance, cerebral infarction, database, medication, SQLite, smartphone

1. Introduction

In recent years, it become a problem that compliance does not continue (that is “non-compliance”) in disease such as cerebral infarction, ischemic heart disease, diabetes, hypertension, and asthma that require patient long term medication. It is daily practice that the outpatients of those disease cause serious accident from non-compliance [1]. Here the non-compliance means that patient dose not take medicine as prescription. For example, the driver who had a brain bleeding while driving caused four people fatal and injury accident in Aoi-ku, Sizuoka Prefecture, in March 7, 2013. Six

elementary school children were killed hit by a crane truck driver who had an epileptic seizure, in Kanuma, Tochigi Prefecture, in April 17, 2011 [2]. Mortality rate of the cerebral infarction patient is the highest in adult disease [3]. Moreover recurrence probability of the cerebral infarction is high (10% within a year, 50% within ten year), and the patient easily becomes critical situation when the recurrence occurs [4]. The outpatient of cerebral infarction has to keep medication every day for long term. Various reasons of the non-compliance could be considered [5], [6]. Since symptom of outpatient usually dose not change suddenly under long-term medication, prescription period is long (e.g. a few a

month) and the outpatient dose not need to come often to hospital and dispensing pharmacy. The outpatient then becomes less communication with doctors and pharmacists. It thus becomes often difficult for the outpatient to make effort in understanding disease, to keep intensity to involve oneself toward planning medical treatment, and to keep having purposes to treat own disease. The outpatients under long-term medication also very often have no subjective symptoms and this cause low adherence. Moreover it is also one of problems that recent change of the environment surrounding medical institutions causes insufficient time for guidance of medical treatment and drug medication in clinic and dispensing pharmacy.

In this paper, we propose medication support system for the outpatient under long-term treatment, who has disease and present a simple and low-cost implementation of the system using the SQLite database engine embedded on the terminals. The remaining part of the paper is organized as follows. In Section 2 and 3, related researches and problems are showed and proposed system architecture and implementation are presented. Section 4 gives future research plan and section 5 concludes the paper.

2. Related Research and Problem

We had developed an interactive communication system for supporting outpatient medical treatment with dispensing pharmacy [7], [8]. We had also conducted field trial of the communication system between outpatients and pharmacists at dispensing pharmacy [9]. The field trial resulted in dramatically improvement of the compliance and intention of the most outpatients under short-term medication. On the other hand, some outpatients under long-term medication had some problems. For example, when patients had almost no change in symptoms with same medication for several years, some patients thought that there was no need to continually report compliance status to pharmacists in dispensing pharmacy in dosing time every day. This was because that the system alerted in every dosing time (one to three times a day) and required the outpatients to report their compliance status to the pharmacist in dispensing pharmacy. Some pediatric patients participating in this trial were having medication over several years because of diseases such asthma and allergies, and the proposed system was particularly burdensome for the parents of these children. Furthermore, some visualization of the compliance status and symptom was requested from many test subjects, since the outpatient might get tired to only communication function from comments obtained in the questionnaire.

We had proposed the communication system to reduce

Fig. 1 Proposed system architecture

the burdensome for the outpatient under long-term medication, with pharmacists in the dispensing pharmacy [10]. In the proposed system, the outpatient terminal featured displays of compliance status and symptom-simulated animation, contact functions to dispensing-pharmacy (e.g. call, text and voice messages). The pharmacist terminal featured response functions to contacts from patients, displays of compliance status and symptom-simulated animation same as the patient terminal. The outpatient only has to select and put the button of "took medicine" or "did not take medicine" in every dosing time (one to three times a day). Outpatient and pharmacist also only have to contact each other as necessary. However, these features of the outpatients and dispensing pharmacy terminals were implemented on web server using MySQL database engine, and web server thus needed to be introduced in dispensing-pharmacy. Because of information security in medical treatment, the database could not be put on Internet cloud.

3. Proposed System

The proposed system in this work, dose not use web

server and MySQL database engine, and uses SQLite database engine on the terminals to try to realize simple and low-cost medication support system.

3.1 Database

This system uses a relational database management system (RDMS) due to the need to store a large amount of data such as compliance status, symptom-simulated animation, call, text and voice messages with patient ID. A RDMS can perform processes such as searching, sorting, extracting, and tabulating against a large quantity of data at high speed and allows data to be manipulated using original instructions based on Structured Query Language (SQL) [11],[12]. There are a variety of RDMS-type database systems such as MySQL, PostgreSQL, SQL Server, Oracle database, Access and SQLite [13]. We used SQLite in the proposed system, which was embedded on terminal, open source software and the most widely used free development environment for smartphone [14]. Web server then could be eliminated. Figure 1 shows the proposed medication support system for the outpatient under long-term treatment, using SQLite.

The SQLite database is independently operated in the each outpatient terminals and pharmacist terminal, respectively. The database in the outpatient is composed of the compliance status (“took medicine”, “did not take medicine” and “N/A”), own text and voice messages sent to pharmacist of oneself, and text and voice messages received from pharmacist. The database in the pharmacist terminal is composed of the outpatient ID, the compliance status, text and voice messages received from the outpatient, and own text and voice messages sent to the outpatient. Daily caused compliance status and messages only are transmitted through simple mail transfer protocol (SMTP) and stored into the SQLite database. The outpatient can always check the own compliance status and messages sent to pharmacist, and messages received from pharmacist, by managing the SQLite database of the own terminal. The pharmacist can always check all outpatients compliance status and messages, and their own messages sent to the outpatients.

3.2 Outpatient terminal

Figure 2 shows a prototype of screen display of the outpatient terminal on iPad2 (Wi-Fi model, iOS Ver. 5.1.1). The outpatient terminal features four functions: input of compliance status (“took medicine” or “did not take medicine”), contact to pharmacist (e.g. call, text and voice messages), notification of incoming from pharmacist, display of 3D simulation of cerebral infarction and compliance rate, as shown in Fig. 2. Here details of

Fig. 2 Screen display of outpatient terminal

Fig. 3 Screen display of compliance rate

the four functions are shown as below.

(a) Input of compliance status In order to reduce labor for reporting compliance status, we designed only two button menus “took” or “did not take” in pop-up window that are shown up with the content of the prescription and alert sound in every preset dosing time, as shown in fig. 2. Soon after the outpatient selected the button, the compliance status data with outpatient ID and time is stored into the database in one’s terminal, and is transmitted to the pharmacist terminals in the dispensing pharmacy.

(b) Contact to pharmacist In order to reduce labor for reporting compliance status, we designed three function of the contact to the dispensing pharmacy: for call, text and voice messages. The three buttons for these functions are arranged below on the screen display of the terminal, as shown in fig. 2. Text and voice message functions are prepared for the outpatients to freely ask pharmacists question, when it is hard to ask the question with telephone call. The three different access way enables the patient to access pharmacist depending on the situation of the patient and pharmacist.

(c) Notification of incoming from pharmacist The pop-up window is shown up with pharmacist name when there is some contact from the pharmacist. The pop-up

(a) Thrombus level 1

(b) Thrombus level 2

(c) Thrombus level 3

(d) Thrombus level 4

Fig. 4 3D simulation of atherothrombotic infarction

(a) Thrombus level 1

(b) Thrombus level 2

(c) Thrombus level 3

(d) Thrombus level 4

Fig. 5 3D simulation of lacunar infarction

window is arranged upper left on the screen display of the terminal, as shown in fig. 2. When the outpatient touches the pop-up window, the top screen display is switched to the screen display of the database. Detail of the pharmacist contact is described in next section.

(d) Display of compliance rate Figure 3 shows the screen display of the compliance rate that is persistency of

medication according to prescription. Compliance rate P is the degree to which patients correctly take medicine following prescription instructions and is expressed as following simple formula [4]:

$$P = \frac{M}{N} \times 100 \quad [\%] \quad (1)$$

where M is the number of times of that patient took medicine completely, and N is the number of days from dosing starts. Plabix, that is one of antiplatelet drugs for cerebral infarction, is usually taken once a day with or without food. Visualizing medication persistence rate make easy to grasp the compliance status backward and raise medication adherence.

(e) Display of 3D simulation of cerebral infarction

Visualization of unseen symptoms in the cerebral infarction could provide the outpatients some help to increase adherence in medication. There are mainly three types in cerebral infarction: atherothrombotic, lacunar and cardiogenic infarctions that are 32, 33 and 27% by ratio, respectively. We then designed the most two types: atherothrombotic and lacunar infarctions, this time for trial. Figure 4 and 5 show different thrombus levels of 3D simulations of atherothrombotic and lacunar infarctions, respectively, that we designed by using Blender. Blender is the free and open-source 3D computer graphics software used for creating animation, visual effects and art [15]. The simulation of the blood flow is based on real blood composition (erythrocytes: 95%, leukocytes: 4%, platelets 1%). For this implementation, we designed four thrombus levels of blood flow-(a), (b), (c) and (d), in atherothrombotic and lacunar infarctions, respectively. The four simulation are switched depending on the compliance status. In the case of the atherothrombotic infarction, the thrombus, that is a lump of denatured cholesterol, becomes large and the blood flow worsens, when the compliance status becomes worse. In the case of the lacunar infarctions, the atheroma also becomes large and the atheroma easily intercepts the blood flow in a thin blood vessel. The 3D simulations are always displayed in backside of menu icons and pop-up windows, as shown in Fig. 2.

The proposed system targets “Plabix,” which is a medicine for the cerebral infarction. The effect of “Plabix” begins to appear after about twenty-four hours after taking and requires about three days for being in a stationary state [16], [17]. In one dosing, the period of the effect lasts about ten days, which is a life of blood platelets, as the effect becomes gradually weak. From these effects, we formulate criteria to select the thrombus level 1 to 4 using following weighted moving average:

$$X_n = \frac{nP_1 + (n-1)P_2 + \cdots + 2P_{n-1} + P_n}{n + (n-1) + \cdots + 2 + 1} \quad (2)$$

where X_n is weighted moving average of recent n days, n is measurement days of the moving average within a prescribed period, P_n is compliance status of n -th day. $P_n=1$ when the outpatient took medicine and $P_n=0$ when

ID	名前	服薬状況	報告	CALL	MAIL	VOICE
156	日大太郎	○	○	○	○	○
157	日大次郎	○	○	○	○	○
158	日大花子	×	×	○	○	○
159	日大三郎	○	○	○	○	○
160	日大孝子	○	○	○	○	○
170	電気太郎	○	○	○	○	○
171	電気太郎	×	○	○	○	○
172	電気花子	○	○	○	○	○

Fig. 6 Screen display of top menu in pharmacist terminal at dispensing pharmacy

the outpatient did not take medicine, respectively. The four thrombus levels in the 3D simulation is switched using threshold values as below:

$$\text{Thrombus level 1, when } Th_1 < X_n \quad (3)$$

$$\text{Thrombus level 2, when } Th_2 < X_n \leq Th_1 \quad (4)$$

$$\text{Thrombus level 3, when } Th_3 < X_n \leq Th_2 \quad (5)$$

$$\text{Thrombus level 4, when } X_n \leq Th_3 \quad (6)$$

where Th_1 , Th_2 and Th_3 are threshold values to switch the simulation to the thrombus level 1, 2 and 3, respectively. These threshold values can be set freely for the doctors and the outpatients.

3.3 Pharmacist terminal

We designed functions of the pharmacist terminal for the pharmacist to get the compliance status of the outpatients and to handle the status and contacts from the outpatients, easily and quickly. The pharmacist terminal at the dispensing pharmacy features three functions: response functions to contacts from the outpatients (e.g. call, text and voice messages) and displays of the compliance status and the 3D simulation of cerebral infarction same as those of the outpatient terminal.

(a) Compliance status Figure 6 shows a screen display of the compliance status list of the outpatients, which is top menu in the pharmacist terminal. ID, name, compliance status with or without message, are shown in the list in each outpatient. Compliance status has three states: circle when the information of “took medicine” is transmitted from the outpatient terminals, cross when the information of “did not took medicine” is transmitted, and N/A when the outpatients dose not operate his terminal and then no signal is transmitted. The pharmacist can grasp the outpatient’s compliance status in the list every

day.

(b) Response to outpatient There are three response functions which are call, text and voice messages, in the pharmacist terminal shown in Fig. 6. The pharmacist selects one function of the three depending on the outpatient's situation. For example, the pharmacist transmits voice message such as "Did you take medicine?" or "Why did you take medicine?" to the outpatient, when the compliance status is not transmitted to the pharmacist terminal. When there is still no answer, phone call could be used. Text message could be used in no urgent case, but voice message could be useful method for the pharmacists in the dispensing pharmacy where the pharmacists are very busy to work for dispensing medicine, providing medication guidance, etc.

4. Discussion

The proposed system aims to make outpatient self-check the long-term compliance situation that tends to be forgotten, and to make them notice the condition without any subjective symptom, and then to raise their consciousness of medical treatment. The compliance situation is transmitted to the pharmacy terminal every day, and the pharmacists share the same data as the outpatients and watch them. The pharmacist doubts of accidents and then contacts to the outpatient by contact-to-outpatient functions such as telephone call and voice message, when no data transmitting and poor compliance continues. The pharmacists check the compliance status data with the outpatients face-to-face at the window of the dispensing pharmacy, and provide guidance for medical treatment to the outpatient, using the pharmacist terminal that shares same data as that of the outpatient's terminal. These support at the both dispensing pharmacy and remote home raises quality of medical treatment and provide the outpatients comfortable feeling under watch of the pharmacists.

However, the compliance status transmitted from the outpatients are self-reported, that may be different from actual situation. For example, some patients may report "took medicine" as compliance status, although they do not take medicine in fact. Some patients may touch wrong button. The pharmacists treat and communicate with the outpatients under understanding that the self-report may be different from facts. Communications between the pharmacists and the patients become smooth and active through the use of the proposed system. The 3D simulation of cerebral infarction also is greatly different from the internal status of actual blood. However, clots are formed and the blood flow is blocked by the clots, when non-compliance continues. The presentation of the 3D

simulation to the outpatients possibly raises their consciousness to the medical treatment.

The four thrombus levels in the 3D simulation are switched using Eqs. (2)-(6), where the threshold values used for the simulation switching can be set freely for the doctors and the outpatients. It is impossible to simulate exactly unseen symptoms of cerebral infarction deep inside of human body. Aim of the 3D simulation here is to make the outpatients understand sufficiently symptoms of cerebral infarction and aware of compliance failure making the atheroma grow and intercept the blood flow in a thin blood vessel, every day outside of the clinic. It thus might be effective that threshold levels are set easy for good compliance patients and set strict for bad compliance patients. It is also known that there is a long-term correlation between relapses rate of cerebral infarction and compliance rate shown in Eq. (1). We have to examine how to set the threshold through future field trial.

Fatality of the outpatients of cerebral infarction is serious under chronic condition in rural area and affected area such as Fukushima and Miyagi attacked by east Japan earthquake. The number of patients of cerebral infarction was about 1,400,000 people that was no. 1 place even when comparing to that of cancer, and about 80,000 patients died every year in 2011 [3]. Moreover recurrence probability of the cerebral infarction is high (10% within a year, 50% within ten year), and the patient easily becomes critical situation when the recurrence occurs [4]. The proposed system has some problem in believability of the self-reported compliance status and the 3D simulation of thrombus formation in blood, but the use of the proposed system provide a certain impact to the current compliance situation, considering bad conditions in the outpatients of cerebral infarction as previously described.

5. Conclusion

This paper described needs to support medication of outpatients of cerebral infarction and then we proposed a simple and low-cost medication support system for outpatient under long-term medication. Conventional medication support system used MySQL database engine on web server and thus needed to introduce web server in dispensing-pharmacy. The proposed system realized simple and low-cost by making the database of those compliance status data using the SQLite database engine on the terminals. The outpatient terminal features the displays of compliance status and 3D visualization of unseen symptom, contact functions to dispensing-pharmacy (call, text and voice messages). The pharmacist terminal features response functions to contacts from the outpatients, displays of the compliance

status and the 3D visualization same as that of the outpatient terminal. The compliance status of the outpatients is automatically transmitted to the pharmacist terminal through e-mail connections in each day. We then proposed control method of the 3D simulation by using weighted moving average of the daily compliance status (“took medicine” or “did not take medicine”).

The proposed system possibly makes the outpatients self-check the long-term compliance status that tends to be forgotten, and makes them notice the condition without any subjective symptom, and then to raise their consciousness of medical treatment. We need to make clear the usefulness and the problems of the proposed system through field trial in future.

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