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Development and Evaluation of a Blood Glucose Management System for Reducing the Delay in Measurement

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Abstract

The purpose of this study was to develop and evaluate the blood glucose management (BGM) system, which supports the scheduling of blood glucose measurements for medical staff. This system enables medical staff to continually confirm the instructions of the physicians by measuring blood glucose levels using a smart device (iPod). This paper describes the difference in the delay of the measurement between the BGM system and the non-BGM system. For the iPod device in the BGM system, the desktop device, and the laptop device, the frequencies of a delay under 30 minutes were 94%, 67%, and 80%, respectively (Ryan-test, P <0.01), and that over 30 minutes were 6%, 33%, and 20%, respectively (Ryan-test, P <0.01). We concluded that the BGM system reduced the delay in blood glucose measurements and led to an optimization of the time of measurement.

Keywords:

Electronic Health Records; Hospital Information Systems; Blood Glucose

Introduction

It is well-known that diabetes is one of the most common metabolic disorders. In 2014, the International Diabetes Federation (IDF) estimated that 387 million people had diabetes in IDF regions, which consists of 194 countries [1-9]. In Japan, there were 7.2 million patients with diabetes in 2015. The Japanese Ministry of Health, Labor and Welfare reported that 16% of all inpatients had diabetes in 2014.

Blood glucose control is conducted to keep levels of blood glucose in the normal range for a patient with diabetes. Establishing a normal blood glucose level for inpatients with diabetes is important to prevent complications and infections after surgery [10-24]. For blood glucose control, medical staff have to frequently measure blood glucose levels and register this data in the electronic medical record (EMR) system [25-28]. On the screen of the EMR system, medical staff confirm the instructions ordered by physicians, such as the insulin dose. The time to respond to changes in blood glucose levels is dependent on the difference between the actual recorded time and the scheduled time of measurements of blood glucose levels

When medical staff register blood glucose levels to the EMR system manually, delay in recording, transcription errors and patient misidentification occur [29-30]. In recent years, to prevent these errors, medical vendors have developed a blood glucose tester that transfers the results of the blood glucose test to the EMR system through a wireless network [31]. Although the tester prevents transcription errors of blood glucose levels, it does not prevent the delay in measuring blood glucose levels. The primary reason for the delay is that understanding various measurement orders from physicians is difficult for medical staff. In this study, to reduce the delay in recording blood glucose levels, the author developed the blood glucose management (BGM) system that enables medical staff to understand the schedules of the blood glucose control ordered by physicians.

The purpose of this study was to develop and evaluate the BGM system that supports the scheduling of blood glucose measurements for medical staff.

Study setting

DAISEN is an EMR system comprising various departmental healthcare systems for all outpatients and inpatients in the Tottori university hospital. As an EMR system, DAISEN records data of blood glucose measurements linked with the instructions ordered by physicians. Use of clinical data from DAISEN for this study was approved by the institutional review board of the Tottori university hospital.

The data for this study were extracted from the records in the EMR system, which consisted of blood glucose levels of inpatients with type 2 diabetes who were admitted to the hospital between Jan 1, 2014 and Oct 1, 2016. The number of selected patients before installation of the BGM system was 3,285 and the number of selected patients after installation of the BGM system was 2,847. To extract the delay in measuring blood glucose levels, we obtained the time that physicians requested the measurement using the EMR system and the time that the blood glucose level, measured by the blood glucose tester, was recorded by medical staff in the EMR system. The authors defined the delay in recording blood glucose levels as the difference between the requested and recorded time. We obtained 35,836 and 9,698 data records with desktop and laptop devices, respectively, as evaluation data before installation of the BGM. After installation of the BGM system, we obtained 93,639 data records with smart devices (iPod).

Evaluation of the BGM system

Analytical processes of evaluation for BGM system are as follows.

Delay time of recording blood glucose level to EMR system

To measure the delay in transferring blood glucose levels into the BGM system and in the non-BGM system, the authors defined the delay as the difference between the time that the blood glucose measurements were recorded by medical staff and the time that the measurement was requested by physicians.

The Occurrence rate of missed measurement or recording of blood glucose levels

To calculate the occurrence rate of non-existing blood glucose value in the EMR system, the author defined missed measurement or recording of blood glucose level as when medical staff did not measure blood glucose level within 60 minutes from the designated time by the physician.

Experimental devices

In this study, the authors developed the BGM system, which consisted of a blood glucose tester, an iPod, and a blood glucose data transfer adaptor (Table 1).

The blood glucose tester was used to measure the blood glucose level of inpatients with diabetes. The data transfer adaptor was used to transfer the data of the blood glucose levels and the execution time recorded by the blood glucose tester to an iPod.

Medical staff used an iPod to transfer the data to the EMR system. Functions of the application installed on the iPod to support the scheduling of blood glucose measurements are described in Table 1.

Table 1 – Experimental devicies.

Device	Hardware/Operating System
Application	• iPod touch A1421/iOS 9.3
Blood glucose tester	• One Touch Verio pro plus
Data transfer adapter	• ebase data transfer adapter P-model
EMR system	• IBM Power System E870/AIX(Clinical Information system)

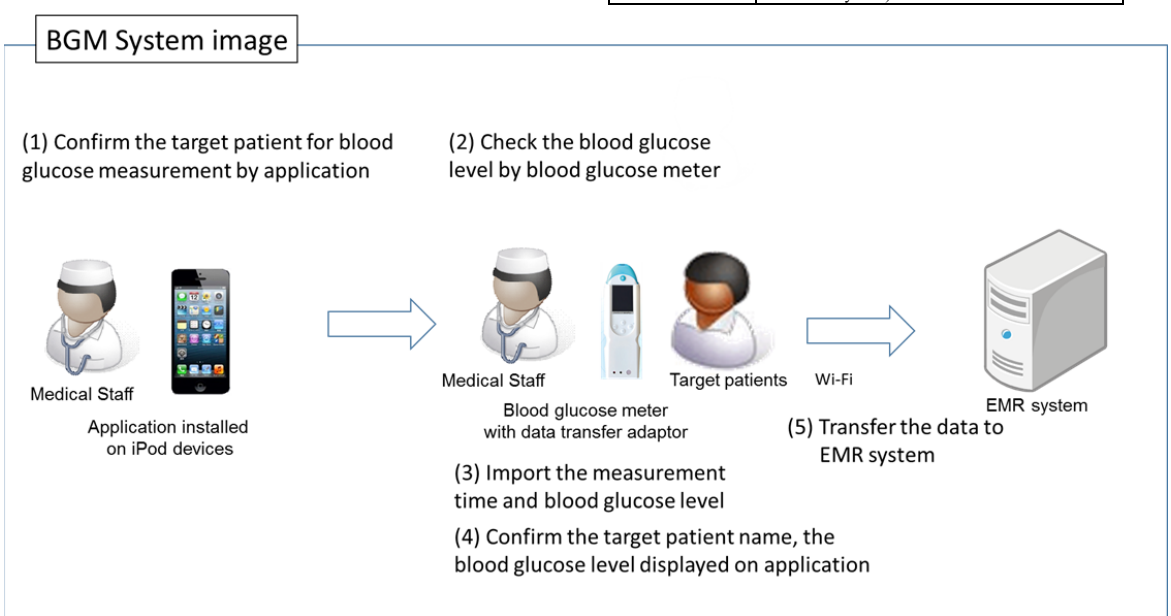

Figure 1 – Blood glucose measurement by the BGM system

With the use of the Objective-C programming language, the application was developed to display the list of selected patients linked with instructions of physicians and send messages to medical staff to alert them of any delay in recording blood glucose levels. The list of selected patients was extracted from the EMR data using Structured Query Language (SQL). The alert made medical staff carrying an iPod aware of a 15 or 30 minutes' delay in the measurement using sounds or vibration.

Blood glucose measurement with the BGM system consists of five steps (Figure 1).

1. Medical staff confirm the selected patient who needs a blood glucose measurement by using an application on the iPod.

2. Medical staff check the blood glucose level of a target patient using a blood glucose tester with the data transfer adaptor.

3. Medical staff import the measurement time and the blood glucose level from the data transfer adaptor into the iPod to display the data on the screen.

4. Medical staff confirm the selected patient's name, the blood glucose level, and the measurement time displayed on the screen before registration to the EMR system.

5. The application transfers the data to the EMR system through a wireless network.

In the non-BGM system, medical staff manually recorded blood glucose levels to the EMR using a desktop or laptop

device by transferring the measurement values displayed on the blood glucose tester. All desktop devices were located in a nursing station. Laptop devices were placed in a computer cart designed for laptops, which can be carried to the inpatients' bedsides.

Statistical analysis

The delay of 15 and 30 minutes of blood glucose measurements for the BGM system and non-BGM system was calculated to compare the occurrence rates using the Ryan test. P values <0.05 were considered statistically significant. The R software program (version 3.1.2) was used to perform the statistical analysis.

Results

Results of delay time to recording the value to EMR system from measuring blood glucose level

The installation of the BGM system resulted in a significant reduction in the delay of recording blood glucose levels by medical staff. Table. 2 show the occurrence rate of a 15 minute delay in recording blood glucose levels when using an iPod device, desktop device and laptop device. When using an iPod in the BGM system, a desktop device, and a laptop device, frequencies of a delay under 15 min were 77%, 37%, and 53%, respectively (Ryan test, P <0.01); frequencies of a delay under 30 min were 94%, 67%, and 80%, respectively (Ryan test, P <0.01); and frequencies of a delay over 30 minutes were 6%, 33%, and 20%, respectively (Ryan test, P <0.01).

Table 2 - T*he occurrence rate of delay time for each device.*

Devices	Median (h:m:s) *1	Average *2	SD *3	Total*4	Occurrence frequency of a delay of each 15 min			Ryan test (< 15 min vs. > 15 min)	Ryan test (< 30 min vs. > 30 min)
					< 15 (%)*5	15-30 (%)	> 30 (%)		
iPod (BGM)	0:04:37	0:09:07	0:11:14	93764	71702 (76)	16003 (17)	6059 (6)	vs. Desktop p<0.01 vs. Laptop p<0.01	vs. Desktop p<0.01 vs. Laptop p<0.01
Desktop PCs (non-BGM)	0:21:10	0:23:15	0:16:24	9709	3610 (37)	2961 (30)	3138 (32)	vs. Laptop p<0.01 vs. iPod p<0.01	vs. Laptop p<0.01 vs. iPod p<0.01
Laptop PCs (non-BGM)	0:17:56	0:18:38	0:15:23	35904	18943 (53)	9598 (27)	7363 (21)	vs. Desktop p<0.01 vs. iPod p<0.01	vs. Desktop p<0.01 vs. iPod p<0.01

*1 Median of the difference between the time that the blood glucose measurements were performed by medical staff and the time that the measurement was requested by physicians.
*2 Average of the difference between the time that the blood glucose measurements were performed by medical staff and the time that the measurement was requested by physicians.
*3 Standard deviation of the difference between the time that the blood glucose measurements were performed by medical staff and the time that the measurement was requested by physicians.
*4 The total number of blood glucose measurements.
*5 The occurrence rate was defined as the occurrence of a delay of 15 minutes divided by the total occurrence rate recorded for blood glucose levels.

The occurrence rate of missed measurements or recordings

We calculated the occurrence rates of missed measurements or recordings of a blood glucose level for each device environment. As a result, for desktop devices, laptop devices, and iPod devices the occurrence rates are 23%, 16% and 5% respectively. The results for iPod were significantly lower than those for desktop and laptop devices. (P <0.01, Ryan-test)

Discussion

In this study, we showed that our BGM system significantly reduced the delay in recording blood glucose levels and the occurrence rate of missed measurements or recordings compared with non-BGM systems. The results are expected to contribute to accurate blood glucose control. A large number of inpatients after surgery are regulated by blood glucose control with insulin injections. Medication errors with insulin have the potential to result in serious harm, including death [32-37]. When blood glucose control was combined with insulin, measurement or record time of glucose levels was set based on the time of a meal. The time of a meal of inpatients was influenced by the measurement of blood glucose levels because the measurement had to be done before or after the meal. The BGM system notifies medical staff of the instructions by physicians such as the insulin dose. Consequently, there is a possibility of improving medical safety of patients with diabetes by reducing the delay of measurement using the BGM system.

Effectiveness of an iPod in availability and accessibility in the medical field has been reported in recent studies [38]. This study focused on the effectiveness of its use for the measurement of blood glucose levels by medical staff. The results showed that the medical staff with iPod devices carried out the measurement more accurately and recorded the blood glucose levels quicker than the medical staff with other devices. More specifically, the results were interesting in that they showed superiority of an iPod compared to laptop PCs though both devices can easily be carried to the bedside of selected patients.

To prevent a patient misidentification accident, medical records of only one patient can be displayed in a screen of the EMR system. On the other hand, all selected patients who needed blood glucose measurements were displayed in the order they were seen by the physician on the screen of the iPod with the BGM system to allow medical staff to effectively take care of many inpatients in a ward. It is possible that the display of selected patients as described above led to the superiority of an iPod compared to laptop PCs.

Compared with the occurrence rate of missed measurements or recodings for each device, we found that the BGM system contributed to decreasing missed measurements of blood

glucose level. However, the results did not sufficiently clarify the effect on medical safety for real inpatient care. For evaluation of medical safety in clinical settings, further investigations based on other resources such as incident reports by medical staff would be needed.

The application on an iPod enabled medical staff to usually understand the situation of the blood glucose measurement. Thus, it is desirable that all medical staff who measure blood glucose levels always carry an iPod. Although the number of hospitals adopting smart devices such as an iPod for medical use has increased in the recent years, its usage is still considered to be insufficient. Thus, the cost of the BGM system including smart devices remains an issue.

In the future, from the practical perspective, implementation costs need to be discussed to use the BGM system in other medical facilities.

Conclusion

We concluded that the BGM system reduced the delay of measurement and resulted in an optimization of the time of measurement. With the increased use of smart devices such as the iPod in the medical field, the system will likely be implemented to the EMR system in many hospitals.

We conclude that for the iPod device, desktop device, and laptop device, the frequencies of a delay under 30 minutes were 94%, 67%, and 80%, respectively (Ryan test, $P < 0.01$), and over 30 minutes were 6%, 33%, and 20%, respectively (Ryan test, $P < 0.01$).

Transcription errors of the blood glucose level were found in the EMR system before installation of the BGM system. The BGM system can prevent transcription errors of recording blood glucose levels using a data transfer adapter.

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