This paper discusses the use of the UNSW/MedCare home telecare systems as a diabetes management tool. The home telecare system (HTS) has demonstrated its performance in storing and measuring clinical data, scheduling actions, plotting graphs and creating reports to help the care team optimize the management of chronically ill patients (7). The existing home telecare systems has been upgraded and further programmed for the recording of blood glucose measurements (BGL), insulin injection doses, hypoglycemic episodes, dietary intake, and exercise activity. Furthermore, based on those data the system will estimate future blood glucose levels and provide recommendations on insulin doses to bring BGLs within recommended levels.

Keywords: home telecare systems, diabetes, insulin doses adjustment, Markov model.

Introduction

Diabetes is one of major chronic diseases that affect people in the industrialized world. At present, there are over 190 million people with diabetes in the world (1). Diabetes is a disease in which body does not produce insulin (or secretes insufficient insulin) or in which body has high insulin resistance. Insulin is a hormone that keeps the blood glucose levels (BGL) within a normal range of 4.0-10.0 mmol/l.

The Diabetes Control and Complications Trial (DCCT) in United States (2) have shown that good BGL management reduces the risk of late complications, such as visual disorders, heart disease, foot problem and kidney failure.

In Type I diabetes, where the body produces no insulin, the BGL is normally managed by exogenous insulin injections. Before the insulin is injected, the diabetics need to measure their BGL (usually four times a day) and estimate their glucose inputs (food intake and exercise level). Based on that measurements and estimations, they estimate the required insulin dose in order to control their BGL.

However, the literature (3) reports that individuals, especially elderly people, rarely adjust their insulin even though their BGL are high and other tasks such as self-BGL monitoring, injecting insulin and recording of the data in a logbook are accomplished correctly. Possible reasons are “patients did not learn how to do it or they did not understand the rules which were explained to them, or they are not sure enough of their knowledge, uncertainty entailing indecision” (Reach3).

Fortunately, Some studies (4, 5) suggested that telemedicine or computer-assisted care might help diabetics in following therapeutic recommendations or advice. Furthermore,
telemedicine also helps to build up a close relationship between diabetics and all healthcare professionals, which is an important requirement of effective management of chronic illness (6).

Although there are many different telemedicine systems available, we will use a locally developed Home Telecare Systems (HTS) to manage chronic disease like diabetes at home. For managing diabetes, the HTS has the capabilities of:

- reminding / scheduling patients to take measurements or inject insulin as required;
- storing patients’ data, and making it available to the care team over the Internet (hence promoting the relationship between the patient and clinician);
- recommending the required insulin dose;
- predicting BGL in future.

This paper discusses the use of the Home Telecare Systems in diabetes management where BGL levels can be recorded, and insulin dosages recommended to keep BGL level within the required range.

**Home Telecare Systems**

The Home Telecare Systems (7) was originally designed to manage chronic illness, such as chronic heart and lung disease and was developed and trialed by Biomedical Systems Laboratory (BSL) at the University of New South Wales. The HTS system is now TGA approved and is being marketed internationally by MedCare Systems Pty Ltd.

The HTS (see Fig. 1 without the broken line) consists of a home clinical workstation, a wearable ambulatory monitoring unit and a home PC that is able to access the Internet. At present, HTS can be used to measure and record blood oximetry, blood pressure, ECG, heart rate, lung function, body temperature and weight. It is also able to record falls and stumbles by the wireless connected triaxial accelerometer (ambulatory monitor).

The HTS can be scheduled to provide reminders for taking medications, for the collection of clinical signs, providing access to validated health information and the delivery of

![Figure 1. Schematic Diagram of Home Telecare System](attachment:image_url)
HTS for Diabetes Management

Current HTS can be improved so that it can record important data for diabetes management, such as BGL, insulin doses, diet and exercise (see Fig. 1 with broken line). Furthermore, HTS can be used as a diabetes expert system where it can predict future BGL and provide insulin doses recommendations based on recorded data.

HTS will provide more benefits than other diabetes telecare systems (8, 9, 10) because it:
- is able to detect the early sign of health complication, especially heart disease;
- is designed to be relatively low cost, is modular (pick and choose), simple to use and has very limited use of wearable devices to promote user compliance;
- can estimate patient’s energy expenditure and monitor ambulatory condition through the use of triaxial accelerometer;
- can track patient’s weight (i.e. BMI) and blood pressure which are the other targets of managing diabetes.

Modelling Approach

Fig. 2 shows the typical block diagram of BGL system. The level of blood glucose depends on the food intake (glucose input), the exogenous insulin dose and the level of exercise, which can be measured or logically estimated. BGL also depends on other immeasurable parameters, such as level of growth hormone and level of stress.

Since BGL system is stochastic process and today’s BGL depends only on yesterday’s BGL (not on previous days), it is suitable to represent BGL system as a Markov model.

Markov modelling of BGL system had previously been attempted by Santoso and Mareels (11). They divided the system into 3 states \{low, normal, high\} denoted by \{G_1, G_2, G_3\} and used 3 different actions \{less insulin, prescribed insulin, more insulin\}. The system was represented in the following way:

\[
\begin{pmatrix}
G_{1}^{k+1} \\
G_{2}^{k+1} \\
G_{3}^{k+1}
\end{pmatrix} =
\begin{pmatrix}
p_{11}(a) & p_{21}(a) & p_{31}(a) \\
p_{12}(a) & p_{22}(a) & p_{32}(a) \\
p_{13}(a) & p_{23}(a) & p_{33}(a)
\end{pmatrix}
\begin{pmatrix}
G_{1}^{k} \\
G_{2}^{k} \\
G_{3}^{k}
\end{pmatrix}
\]

[1]

where \(p_{ij}(a)\) is the transition probability from \(G_i\) to \(G_j\) as a function of insulin action \(a\), and \(k\) is discrete time.

The Markov model that they developed may predict BGL accurately. However, since the model was trained with a very small number of data, the performance of current model is not acceptable. A large-scale diabetes data is therefore needed to train and test the
Markov model. At present, a clinical trial to collect large-scale is being planned and prepared.

**Algorithm for Recommending Insulin Doses**

Moffitt has explained a comprehensive set of rules for the adjustment of insulin doses in his book (12), which was published by Diabetes Australia. The rules are claimed to be simple, however, no one has attempted to implement them since they are in fact quite sophisticated. The basic rules of the algorithm are:

- Look for a pattern BGL in one day, then make a simple and logical adjustment to insulin dose.
- Also consider any hypoglycemic episodes, diet and exercise activity.
- Then, see what happens and make another adjustment some days later (2 to 3 days).

A decision tree algorithm for recommending insulin doses has been derived from the book (12) and implemented as application program, which can be incorporated to HTS. Based on the algorithm, the program will give one or more recommendations of insulin doses adjustment to the patients, and it is up to them whether to accept one of the recommendations or reject all of them. If the patients reject them, they should make their own judgment about calculating new insulin doses.

**Conclusion**

The home telecare systems have shown its features in ambulatory monitoring of the health parameters, such as: blood pressure and pulse oximetry, ECG, heart rate, weight, body temperature and lung function.

The current system can be further programmed as a diabetes expert system, where it collects all important data, reminds patients in taking measurement or injecting insulin, predict future blood glucose (based on model) and recommends insulin doses adjustment.

**References**

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