Telemonitoring of Blood Glucose and Energy Expenditure of Patients with Diabetes Mellitus to Support Optimization of Insulin Dosing

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Abstract. *There are patients with diabetes mellitus who have to measure their blood glucose several times a day. The purpose of such measurements is to estimate optimal dose of insulin they should take. The amount of insulin needed depends on several aspects: previous insulin dose, amount of sugar in consumed food, previous physical activity of the patient – amount of metabolized energy and of course the measured blood glucose level. It is mostly the patient's responsibility to take into account those values. In case of inappropriate dosing the patient is exposed to a possible hyperglycemic or hypoglycemic shock. Our proposed telemonitoring system allows storing on-line data of patient's movement activity and without any additional patient's control also transmits all measured patient's blood glucose values. This can increase the patient's safety. The system could be useful especially for patients with reduced ability such as very old people.*

Keywords: telemedicine; diabetes mellitus, patient monitoring

Introduction

Diabetes is rapidly growing in prevalence worldwide. The number of people with diabetes was 171 million in 2000 and will grow to 366 million by 2030. One reason for this is a growing elderly population, but younger people are increasingly likely to develop diabetes due to an increase in mean weight and a decrease in exercise. The increasing resources needed to modify lifestyle and appropriately manage diabetes are a worldwide healthcare burden. Promising solutions arise among others from wireless technologies and mobile solutions [1].

Problems which can be solved by mobile solutions require regular monitoring of events and a fast, appropriate reaction to them. In diabetes, the stability of blood glucose level in normal life is an important objective. In addition, promotion of physical activity and exercise as well as dietary compliance may be supported by mobile solutions [1].

One of the most important values which have to be monitored by a patient with diabetes is the blood glucose level. Personal glucometers are often used for measuring. Most glucometers today use an electrochemical method. Test strips contain a capillary that sucks up a reproducible amount of blood. The glucose in the blood reacts with an enzyme electrode containing glucose oxidase. The enzyme is reoxidized with an excess of a mediator reagent. The mediator in turn is reoxidized by reaction at the electrode, which generates an electrical current. The total charge passing through the electrode is proportional to the amount of glucose in the blood that has reacted with the enzyme. For future applications non-invasive devices may enable continuous monitoring. Research is being done on non-invasive methods for measuring blood glucose, such as using infrared or near-infrared light, electric currents, and ultrasound. For now we must settle for a set of discrete measurements.

Telemonitoring system proposal

In our laboratory we have developed a home care mobile patient monitoring system [2]. Currently it is a running complex service including basic patient's mobile telemetric unit, secure centralised server solution, monitoring software and non-stop assistance service [3]. The mobile unit measures movements and location of the patient. The system also checks itself constantly by measuring several technical parameters. The patient can call for help by pressing the only one button it has. The personal inspect mobile unit is shown in Fig. 1 (left). Nowadays this basic standalone unit is used mostly by seniors living alone in their home environment. The service is going to be advantageously extended by further wireless medical peripherals for different sorts of patients.

Diabetics

For the diabetic extension of the system several glucometers have been tested. Finally we have chosen the FORA G31 Blood Glucose Monitoring system, shown in Fig. 1 (right). This glucometers have a possibility to store last thousand measured values in memory and are equipped with an integrated Bluetooth interface.

Fig. 1. Personal inspect mobile sensing unit (left) with wirelessly connected blood glucose meter (right).

Hardware of our 2nd generation mobile unit has been adjusted, another type of 3D accelerometer (ADXL327) has been used and the Bluetooth interface has been added into it. We have used Laird BTM411 modules for this. The firmware has been modified so the mobile unit is wirelessly paired with the glucometer. It detects when the glucometer turns on. After that it waits for receiving just measured value or it can receive other values stored in memory. Finally these values are sent to the server and there processed and stored. All this happens automatically without any additional patient's control. The unit also measures the patient's movement activity, processes signals from the accelerometer and sends them to the server. Trends can be observed from the client application (by the patient or his diabetological specialist). Alarm thresholds to avoid hyperglycemic state or hypoglycemic shock can be set.

Pilot measurements

The system is being tested in cooperation with The Research Center for Diabetes, Metabolism and Nutrition 3rd Medical Faculty, Charles University in Prague. First group of testing patients are pregnant diabetic women or women having gestational diabetes. The percentage of patients with diabetes mellitus consists of a population of about 1.5-2.0% of pregnant women. In case of gestational diabetes is the presence of about 3-4% of all pregnant women. Perinatal morbidity of children of mothers with diabetes mellitus is approximately 3 times higher than children of healthy mothers [4]. Measurement of blood sugar runs eight times a day, movement activity is monitored continuously 24 hours a day.

Results

An option how to monitor the patient's blood glucose level remotely in his home environment has been demonstrated. Working sample of such a system has been made and tested. The system is able to work without any additional patient's control. From the measured movement activity of the patient can be estimated his energy expenditure and the dose of insulin can be than optimized.

Discussion

There is work to be done around algorithms for accurate calculation of energy released during daily exercise. In case of well-located sensing unit measured data are sufficient for this and the calculation may be done by the server side. Algorithms for processing blood glucose trends may be also improved to be able to prevent some critical states. This is going to be discussed with diabetological specialists.

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