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Automated Feedback Based Insulin Regulatory System for Diabetic Patients

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Abstract: *For patients with diabetes especially for Type-I, a.k.a. insulin dependent diabetes, tight control of glucose level is essential. Regulating blood glucose concentration using the insulin infusion device is important for these patients, because they have deficiency of insulin production by pancreas that prevents appropriate metabolism of glucose. This paper is focused to envisage the regulation and management of the concentration of glucose and insulin in the blood of a diabetic. Using this model, a Feedback-loop in a system that regulates and manages the blood glucose-insulin has been designed, implemented and analyzed using Matlab.*
Keywords: *Insulin, Glucose, Diabetes, Type 1.*

I. Introduction

Insulin, a hormone released from the pancreas, controls the amount of sugar in the blood. When people eat or drink, it is broken down into materials, including the simple sugar glucose, that the body needs to function. Sugar is absorbed into the bloodstream and stimulates the pancreas to produce insulin. Insulin allows sugar to move from the blood into the cells. Once inside the cells, it is converted to energy, which is either used immediately or stored as fat or glycogen until it is needed.

If the body does not produce enough insulin to move the sugar into the cells, the resulting high levels of sugar in the blood and the inadequate amount of sugar in the cells together produce the symptoms and complications of diabetes.

For patients with diabetes especially for Type-I, insulin dependent diabetes, tight control of glucose level is essential. Regulating blood glucose concentration using the insulin infusion device is important for these patients, because they have deficiency of insulin production by pancreas that prevents appropriate metabolism of glucose. Many patients, who take insulin infusion in their diabetes therapy, inject insulin with needles and syringes that deliver insulin just under the skin, so that the functions of the pancreas are replaced by some external devices. An external insulin pump is an electro-medical device that delivers insulin through narrow and flexible plastic tubing that ends with a needle inserted just under the skin near the abdomen. The pump releases doses of insulin at meals and during the periods when blood glucose is too high based on measured values of glucose sensors [1].

A patient's glucose concentration may change dynamically depending mostly on his /her physical activities and nutrition, and therefore, the amount of insulin needed varies from time to time. A number of diseases may occur, possibly resulting in life-threatening health conditions if the supply of insulin is not in time or not correctly dosed or fails for some reasons. For example, sustained hyperglycemia (blood glucose exceeding 120 mg/dL) may lead to most of the long-term complications associated with diabetes, such as nephropathy and retinopathy.

II. Prediabetis Conditions

A) Prediabetes

Prediabetes is a condition in which blood sugar levels are too high to be considered normal but not high enough to be labeled diabetes. People have prediabetes if their fasting blood sugar level is between 101 mg/dL and 126 mg/dL or if their blood sugar level 2 hours after glucose tolerance test is between 140 mg/dL and 200 mg/dL. Identifying people with prediabetes is important because the condition carries a higher risk for future diabetes as well as heart disease. Decreasing body weight by 5 to 10 % through diet and exercise can significantly reduce the risk of developing future diabetes.

B) Type 1

In type 1 diabetes (formerly called insulin-dependent diabetes or juvenile-onset diabetes), more than 90% of the insulin-producing cells of the pancreas are permanently destroyed. The pancreas, therefore, produces little or no insulin. Only about 10% of all people with diabetes have type 1 disease. Most people who have type 1 diabetes develop the disease before age 30.

Diabetes mellitus is a metabolic disorder in which insulin, a kind of hormone which promotes the uptake of glucose into cells, cannot properly perform its role. People with diabetes cannot produce enough insulin that is required to convert sugar, starches and other food into energy needed for daily life. Diabetes Mellitus is so far an incurable disease affecting million of people worldwide.

III. Hyperglycemia Condition

Hyperglycemia is common in critically ill patients and is not limited to patients who are known to be diabetic. Several recent studies have established a correlation between tight glucose control and decreased preoperative morbidity and mortality in surgical and critically ill patients. Applying these findings to improve outcomes involves identifying patients at risk for hyperglycemia, monitoring blood glucose frequently, using an effective insulin infusion algorithm to control blood glucose within a narrow range, and adjusting insulin infusion rates in a timely and accurate manner. Adverse effects of hyperglycemia include dehydration, increased susceptibility to infection, and impaired wound healing. In fact, there are some data to suggest that aggressive glycemic management can help combat infection and several studies have showed a strong association between hospital mortality and glycemic levels.

IV. Proposed Architecture

A number of algorithms for controlling glucose levels with insulin infusions are currently in use throughout the world. Most of these protocols specify adjustments in insulin infusion rates based on hourly measurements of blood glucose with rescue administration of glucose for hypoglycemic episodes. The development of insulin injection programs has generally proceeded along two fronts: Conventional method and Feedback loop method [3].

A. Conventional method

Conventional systems deliver a predetermined amount of insulin to the patient and the amount of insulin is based on the insulin curve of the normal pancreas secretion. This system is an open loop system and doesn't involve any feedback loop. Conventional control block diagram shown in Fig.1.

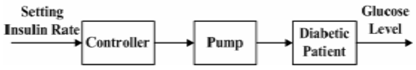

Figure 1. Conventional control for diabetics

In this method since feedback loop is not involved, continuous automatic monitoring of insulin is not possible and it has to be delivered manually whenever needed.

B. Feedback Loop Method

In the Feedback-loop control system, a glucose sensor is needed that can measure blood glucose level. This information then would be passed to a control system that would calculate the necessary insulin delivery rate to keep the blood glucose level in a stable range. Then an electro-medical device will deliver the desired amount of insulin. In general, the Feedback-loop method is more reliable in maintaining the level of blood glucose and also is close to the normal pancreas [4]. Fig.2 shows the block diagram of Feedback-loop control of diabetes patients.

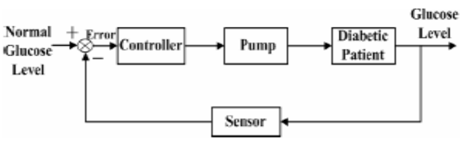

Figure 2. Close-loop control for diabetics

For patients with diabetes especially for Type-1, insulin dependent diabetes, tight control of glucose level is essential. Regulating blood glucose concentration using the insulin infusion device is important for these patients, because they have deficiency of insulin production by pancreas that prevents appropriate metabolism of glucose. Many patients, who take insulin infusion in their diabetes therapy, inject insulin with needles and syringes that deliver insulin just under the skin, so that the functions of the pancreas are replaced by some external devices. An external insulin pump is an electronic medical Device that delivers insulin through narrow and flexible plastic tubing that ends with a needle inserted just under the skin near the abdomen. The pump releases glucose is too high based on measured values of glucose sensors [5].doses of insulin at meals and during the periods when blood.

It is urgent to design a continuous Feedback-loop control system for insulin infusion. The continuous control would be a great improvement in the daily treatment of diabetes, especially in some cases that medical persons are not presented or the patients have less knowledge about the disease. Such an automatic control will benefit patients and avoid some mistakes during injections and operations [5].

IV. System Architecture

A) Glucose-Insulin Regulation Model

In order to study the effects of glucose and insulin regulation in body we need a model of a pancreatic function. One of the main functions of the pancreas is to regulate the glucose concentration in the blood through release of the enzyme insulin. In a normal patient, insulin tightly regulates the metabolism of glucose. Diabetes patients suffer from a dysfunction of this process. The glucose-insulin regulation model used is based on Stolwijk and Hardy's dynamic model [5]. The model was modified by adding a term for exogenous insulin infusion. Hence, the glucose dynamics are governed by following equations [5]. Therefore, our work is based on the research carried out by [1-5].

$$C_G \frac{dG}{dt} = U_G + Q_G - \lambda G - \nu GI, \qquad G \leq \theta \qquad \text{eq.1}$$

$$C_G \frac{dG}{dt} = U_G + Q_G - \lambda G - \nu GI - \mu (G - \theta), \quad G > \theta, \qquad \text{eq.2}$$

$$C_I \frac{dI}{dt} = U_I - \alpha I \qquad G \leq \varphi \qquad \text{eq.3}$$

$$C_I \frac{dI}{dt} = U_I - \alpha I + \beta (G - \varphi) \qquad G > \varphi \qquad \text{eq.4}$$

Where,
G = Instantaneous blood glucose level in mg/dl
I = Instantaneous blood insulin level mU/d
U_G = Exogenous glucose infusion in mg/h
U_I = Exogenous insulin infusion in mU/h
C_G = Glucose capacitance in the extra cellular space
C_I = Insulin capacitance in the extra cellular space
O_G = Glucose inflow into blood in mg/h
Λ= Tissue usage rate of glucose that is independent of I (t)
N = Tissue usage rate of glucose that is dependent on I (t)
A= Insulin destruction rate
B= Insulin production rate by the pancreas
Θ= Threshold for renal discharge of glucose
Φ= Threshold for pancreatic production of insulin
μ = Constant proportionality factor (gain)

Glucose inflow into the blood can be either through absorption from the gastrointestinal tract or through production from the liver. In addition, as seen from the parameter descriptions above, the coefficients have physiological significance, and also differ depending on the condition of the patient. Type-1 Diabetic Mellitus (DM) patients lack the capacity to produce adequate amounts of insulin, The glucose-insulation regulation model, which is described in equations (1) and (2) and comprises an internal feedback loop provided by the pancreas, can be thought of as a two-input and two-output dynamic system as shown in Fig.3

Figure 3. Two-input Two-output pancreatic model

VI. Results And Conclusions

Fig. 4 demonstrates the blood glucose concentration in mg/dl against time interval which is taken into minutes to match the practical approach of the diabetic.

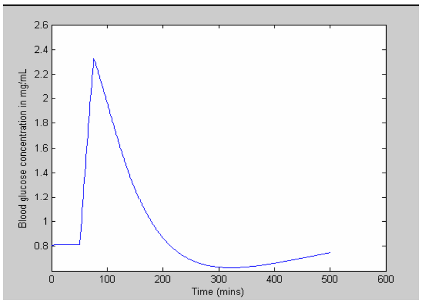

Figure 4. Blood Glucose Concentration (X)

Fig. 5 demonstrates the infusion of level of insulin in mU/ML against time interval. It is to be pointed out that, the release of level of insulin is according to the level of glucose level thereby regulating and managing the amount of insulin to be required by a diabetic on different time intervals.

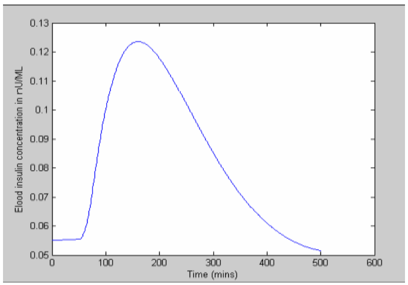

Figure 5. Blood Insulin concentration

In this Feedback-loop system, the demonstrated results have taken into account the different modes of glucose level like fasting or random because it really plays a very important role in the management of insulin for diabetic.

V. Conclusion

The analysis based on the results obtained on the proposed model show significant regulation and management of the glucose-insulin by exhibiting notable proportion of parameters. A Feedback-loop pancreatic model for the regulation and management of glucose-insulin has been designed, implemented and analyzed by using dynamic equation parameters for the diabetics. The model is simulated with the help of Matlab.

References

[1] Pinky Dua, Francis J .Doyle, and Pistikopoulos, "Model-Based Blood Glucose Control for Type 1 Diabetes via Parametric Programming," IEEE Transactions on Biomedical Engineering, vol.53, pp.1478-1491, August 2006

[2] Nicolas W. Chbat, Tuhin K. Roy "Glycemic Control in Critically Ill Patients – Effect of Delay in Insulin Administration" Proceedings of the 2005 IEEE Engineering in Medicine and Biology 27th Annual Conference Shanghai, China, September 1-4, 2005

[3] Zlatko Trajanoski, Paul Wach, "Neural Predictive Controller for Insulin Delivery Using the Subcutaneous Route,"IEEE Transactions on Biomedical Engineering, vol.45, pp: 1122-1134, 1998

[4] J.Geoffrey Chase,Z-H Lan,J-Y Lee,and K-S Hwang, "Active Insulin Infusion Control of the Blood Glucose Derivative," Seventh International Conference on Cootrol, Automation, pp.1162-1167,December 2002

[5] Jiming Chen, Kejie Cao, 1 You Xian Sun, Yang Xiao, and Xu (Kevin) Su, "Continuous Drug Infusion for Diabetes Therapy: A Feedback-Loop Control System Design" Received 15 July 2007; Revised 25 November 2007; Accepted 5 December 2007