Long-acting insulin management for blood glucose prediction model

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Introduction: Reliable methods for short term blood glucose level prediction can be efficiently integrated into mobile Ambient Assisted Living (AAL) services for diabetes management. Subcutaneous insulin absorption is one of the key factors beside the meal consumed and the blood glucose history values that such prediction methods must consider. According to the current practice, insulin dependent diabetic patients use a basal or long-acting insulin injection once a day that produces a steady insulin level for the whole day, and bolus injections for every meal in order to control their blood glucose. The mathematical models commonly used blood glucose prediction can handle only bolus insulin in a correct way, which makes effective only for inpatient care. One can simulate the effect of the basal insulin as a single injection of bolus insulin with a slowly rising curve with a very high maximum value. However, in reality the basal insulin level reaches a proper level in a very short time and the effect lasts for a long time. An adjustment to the model is required to properly handle basal insulin in order to reach more accurate results. By substituting the single big dose of basal insulin with a series of smaller bolus insulin doses we can carry out the steady curve of insulin presence in the blood similar to the curve defined by the medicine manufacturers.

Method: We implemented our blood glucose prediction model [1] by combining two state-of-the-art models. The first one models the glucose absorption in two compartments (stomach and intestines) [2]. This model can manage various sorts of food with different glycemic indices and it can also handle the overlap of meals. The other model is based on nonlinear discrete-delay differential equations [3], and it model the blood glucose and insulin control system. The equations of the model describe insulin transfer between subcutaneous insulin depots, insulin absorption into blood and the role of insulin in blood glucose control. In our proposed method, we model the long-acting insulin in a correct way by using a series of smaller insulin doses, instead of one big dose, the original time interval divided into short subintervals with low maximal absorption time (Tmax). We tested the method on a data set of a clinical trial in which 16 insulin dependent patients (7 female and 9 male) used a Continuous Glucose Monitor (CGM) device to record their blood glucose levels for six days, while their meals were recorded. In order to test the proposed method, we used 4 profiles of basal insulins, each profile having a specific number of doses, dose amounts, injection times and Tmax values, thus simulating the original basal insulin injection. We applied the original model and the corrected model to predict short term (180 mins) blood glucose levels with various basal insulin profiles and computed the average absolute error of the prediction compared to the CGM records.

Results: The average improvement achieved by the correction was 0.63 mmol/l and the biggest improvement was 2.37 mmol/l. In some special cases the average error increased due to the improved basal insulin model (in case of Lantus and Levemir insulins). Table I show the results.

	Profile 1	Profile 2	Profile 3	Profile 4
Average improvement (mmol/l)	0.57	0.63	0.44	0.55
Biggest improvement (mmol/l)	2.37	2.35	2.32	2.35
Worse results (data set)	3	4	5	3

TABLE I. Average improvement, Biggest improvement and Worse results data for each insulin profile

We also analyzed the prediction accuracy at the next meal time. A frequently used measure in the literature is the ratio of error, i.e. the rate of prediction errors less than 3 mmol/l. We

can state that in 5 cases more than 50% of the errors were within 3 mmol/l, in 11 cases it was between 30% and 50%. In two cases, it failed to achieve an acceptable result. Figure I shows results of two day's test for P11 patient.

FIGURE I. Prediction of Blood Glucose Level at the next meal time for P11 patient.

Conclusion: It is difficult to compare our results for long-acting insulin management in blood glucose prediction with the literature because to our best knowledge no research has been published in exactly this field so far.

Our results without correction were not far from the best results published [4]. The average improvement of more than 0.6 mmol/l earned by the correction is remarkable. This improvement, combined with the expected improvement from the planned management of other factors like stress, insulin sensitivity and physical activity, could make our prediction model more efficient and reliable as a module of the Lavinia lifestyle mirror mobile application [5] for outpatient healthcare.

References

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