Development of a Neural Network for Prediction of Glucose Concentration in Type 1 Diabetes Patients

Scott M. Pappada, B.S.,[1] Brent D. Cameron, Ph.D.,[1] Paul M. Rosman, D.O., F.A.C.P., F.A.C.E.[2]

Abstract

Background:

A major difficulty in the management of diabetes is the optimization of insulin therapies to avoid occurrences of hypoglycemia and hyperglycemia. Many factors impact glucose fluctuations in diabetes patients, such as insulin dosage, nutritional intake, daily activities and lifestyle (e.g., sleep-wake cycles and exercise), and emotional states (e.g., stress). The overall effect of these factors has not been fully quantified to determine the impact on subsequent glycemic trends. Recent advances in diabetes technology such as continuous glucose monitoring (CGM) provides significant sources of data, such that quantification may be possible. Depending on the CGM technology utilized, the sampling frequency ranges from 1–5 min. In this study, an intensive electronic diary documenting the factors previously described was created. This diary was utilized by 18 patients with insulin-dependent diabetes mellitus in conjunction with CGM. Utilizing this dataset, various neural network models were constructed to predict glucose in these diabetes patients while varying the predictive window from 50–180 min. The predictive capability of each neural network within the fully trained dataset was analyzed as well as the predictive capabilities of the neural networks on unseen data.

Methods:

Neural network models were created using NeuroSolutions® software with variable predictive windows of 50, 75, 100, 120, 150, and 180 min. Neural network models were trained using patient datasets ranging from 11–17 patients and evaluated on patient data not included in the neural network formulation. Performance analysis was completed for the neural network models using MATLAB®. Performance measures include the calculation of the mean absolute difference percent overall and at hypoglycemic and hyperglycemic extremes, and the percentage of hypoglycemic and hyperglycemic occurrences were predicted.

Author Affiliations: [1]Department of Bioengineering, University of Toledo, Toledo, Ohio; and [2]Departments of Medicine at: Humility of Mary Health Partners, St. Elizabeth Health Center, Youngstown, Ohio; St. Joseph Health Center, Warren, Ohio; Forum Health, Northside Medical Center, Youngstown, Ohio; Trumbull Memorial Hospital, Warren, Ohio; University of Toledo, College of Medicine, Toledo, Ohio; Northeastern Ohio Universities, College of Medicine, Rootstown, Ohio; Ohio University, College of Osteopathic Medicine, Athens, Ohio; and Case Western Reserve University, College of Medicine, Cleveland, Ohio

Abbreviations: (AD%) absolute difference percent, (ANN) artificial neural network, (CGM) continuous glucose monitoring, (CGMS) continuous clucose monitoring system, (GUI) graphical user interface, (MAD%) mean absolute difference percent

Keywords: neural network, diabetes, glycemic predictions, CGM

Corresponding Author: Brent D. Cameron, Ph.D., Department of Bioengineering, University of Toledo, 5030 Nitschke Hall, Toledo, OH 43606-3390; email address *brent.cameron@utoledo.edu*

Abstract cont.

Results:
Overall, the neural network models perform adequately at predicting at normal (>70 and <180 mg/dl) and hyperglycemic ranges (≥180 mg/dl); however, glucose concentrations in areas of hypoglycemia were commonly overestimated. One potential reason for the "high" predictions in areas of hypoglycemia is due to the minimal occurrences of hypoglycemic events within the training data. The entire 18-patient dataset (consisting of 18,400 glucose values) had a relatively low incidence of hypoglycemia (1460 CGM values ≤70 mg/dl), which corresponds to approximately 7.9% of the dataset. On the contrary, hyperglycemia comprised approximately 35.7% of the dataset (6560 CGM values ≥180 mg/dl), and euglycemic values allotted for 56.4% of the dataset (10,380 CGM values >70 and <180 mg/dl). Results further indicate that an increase in predictive window leads to a decrease in predictive accuracy of the neural network model. It is hypothesized that the underestimation of hyperglycemic extremes is due to the extension of the predictive window and the associated inability of the neural network to determine oscillations and trends in glycemia as well as the occurrence of other relevant input events such as lifestyle, emotional states, insulin dosages, and meals, which may occur within the predicted time window and may impact or change neural network weights.

Conclusions:
In this investigation, the feasibility of utilizing neural network models for the prediction of glucose using predictive windows ranging from 50–180 min is demonstrated. The predictive windows were chosen arbitrarily to cover a wide range; however, longer predictive windows were implemented to gain a predictive view of 120–180 min, which is very important for diabetes patients, specifically after meals and insulin dosages. Neural networks, such as those generated in this investigation, could be utilized in a semiclosed-loop device for guiding therapy in diabetes patients. Use of such a device may lead to better glycemic control and subsequent avoidance of complications.

J Diabetes Sci Technol 2008;2(5):792-801