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SYMPOSIUM

A Model of Self-Treatment Behavior, Glucose Variability, and Hypoglycemia-Associated Autonomic Failure in Type 1 Diabetes

Marc Breton, Ph.D., William L Clarke, M.D., Leon Farhy, Ph.D., and Boris Kovatchev, Ph.D.

Abstract

Background:

Type 1 diabetes patients face a lifelong behaviorally controlled optimization problem: maintaining strict glycemic control without increasing the risk of hypoglycemia. Because internal insulin secretion in type 1 diabetes (T1DM) is practically absent, this optimization is entirely dependent on the interplay among (i) self-treatment behavior, (ii) interaction between exogenous insulin and carbohydrates utilization, and (iii) internal defenses against hypoglycemia. This article presents a mathematical model and a computer simulation of the relationship among self-treatment in T1DM, blood glucose (BG) variability, and hypoglycemia-associated autonomic failure (HAAF).

Method:

A stochastic behavioral self-control process was coupled with a dynamical system simulation of the dampening effect of counterregulation on BG oscillations. The resulting biobehavioral control system was compared to data from a field clinical trial (85 T1DM patients, 21–62 years old, T1DM of at least 2 years duration, and at least two documented severe hypoglycemia episodes during the previous year).

Results:

The mathematical simulation was able to reproduce characteristics of hypoglycemic events observed during a field clinical trial, such as temporal clustering of hypoglycemic episodes associated with HAAF and occurrence of severe hypoglycemia as a result of periods of HAAF augmented by increased BG variability.

Conclusion:

This investigation offers a mathematical model of HAAF—the primary barrier to intensive insulin treatment. This combined modeling/computer simulation/data analysis approach explains the temporal relationship among behaviorally induced hypoglycemia, glucose variability, and autonomic failure in T1DM. This explanation is valuable not only because it indicates that signs of HAAF can be detected in patients' natural environment via self-monitoring or continuous glucose monitoring, but also because it allows for tracking of the risk of severe hypoglycemia over time.

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Author Affiliation: School of Medicine, University of Virginia, Charlottesville, Virginia

Abbreviations: (BG) blood glucose, (CR) counterregulation, (HAAF) hypoglycemia-associated autonomic failure, (SH) severe hypoglycemia, (T1DM) type 1 diabetes, (T2DM) type 2 diabetes

Keywords: counterregulation, HAAF, hypoglycemia, modeling, risk of hypoglycemia, simulation

Corresponding Author: Marc Breton, Ph.D., Diabetes Technology Center, P.O. Box 400888, Charlottesville, VA 22904-4888; email address mb6nt@virginia.edu